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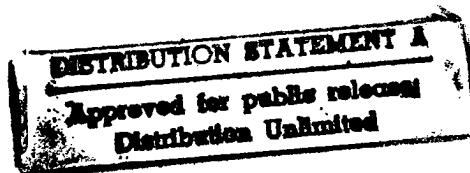
***Central Eurasia: Engineering &  
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CONVERSION OF URANIUM MINING ENTERPRISES

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SCIENCE & TECHNOLOGY  
CENTRAL EURASIA: ENGINEERING & EQUIPMENT  
CONVERSION OF URANIUM MINING ENTERPRISES

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Round Table: Conversion Problems of Mining Enterprises of the USSR  
Ministry of Nuclear Engineering and the Nuclear Power Industry  
[Minatomenergoprom SSSR]

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[*"Round Table"* of GORNYY ZHURNAL with Yu. V. Dorofeichev, V. F. Zaytsev,  
Yu. M. Proshin, Ye. N. Kamnev, V. M. Kirpichenko, V. N. Sytenkov, V. N. Mosinets,  
F. I. Pasechnik, V. N. Fanshteyn, B. A. Zavyalov, D. P. Lobanov, Yu. N. Soroka, A. N.  
Lukyanov, L. B. Prozorov, Ye. A. Kotenko, Yu. A. Prokopovich, D. P. Lobanov and  
V. I. Filonets]

[Text] As already reported in these pages, the editorial staff of GORNYY ZHURNAL  
has held a "round table" based at the All-Union "Order of the Red Banner of Labor"  
Scientific Research Institute for Preliminary Study and Design of Industrial Technology,  
devoted to problems of conversion of the raw material base of nuclear engineering and  
the nuclear power industry.

Taking part in the work of the "round table" were representatives of Minatomenergoprom  
SSSR, the USSR Ministry of Metallurgy, and a number of other industrial ministries and  
agencies.

It is the hope of the editorial staff that publication of the materials of the "round table"  
and a sampling of articles dealing with the work experience of mining and processing  
enterprises of the raw material base of Minatomenergoprom SSSR under conditions of  
conversion of the sector will engage the attention of our readers, and advance the cause  
of more active inculcation of the latest engineering advances now accrued in enterprises  
of the raw material base of Minatomenergoprom SSSR into associated mining industries.

**Yu. V. Dorofeichev**, deputy chief of the First Main Scientific and Engineering  
Administration of the USSR Ministry of Nuclear Engineering and the Nuclear Power  
Industry.



The "round table" organized by the editorial staff of GORNYY ZHURNAL is the first meeting of this kind in our sector of industry, in the course of which we would exchange opinions, and share our concerns and problems with representatives of other mining industry sectors, and also make suggestions that will be of advantage to the entire mining industry of our nation.

The requirement of our nation for uranium raw material has recently been sharply curtailed as a result of a change in the program for development of nuclear engineering and defense needs. Therefore, all collectives in mining enterprises of the USSR (mining-metallurgical, mining-

chemical or mining-enrichment combines) are faced with the task of converting the entire production facility, reprofiling it to do other jobs of no less importance to the national economy. In approaching these problems, the directorate of the Ministry and the Main Administration has developed a Conversion Program that has been examined and approved by the Board of the Ministry, and that defines the tasks of every ore administration and every combine in a number of areas. In developing this Conversion Program, our main goal has been maximum retention of the labor collective of miners, shaft sinking construction workers, technologists, machine builders, and employees in design offices and central research laboratories, for whom we have the highest regard.

The main focus in conversion of our mining industry in connection with the sharp curtailment of uranium production has been directed mainly at assimilating development of deposits of nonferrous and rare metals located in direct proximity to presently existing combines within a radius of 100-150 km. For example, plans call for using the forces of the Tselinnyy Mining-Chemical Combine to begin working industrial diamond, tin and tungsten deposits. As of now, one of these has been explored, and is on the balance sheet of the combine.

Work on increasing the production of refined gold is to be developed in nearly all combines. The mining sector is already working the Muruntau gold ore deposit, using progressive technologies of ore extraction and processing. We are planning to work a number of small gold deposits. New progressive technology for working such deposits has already gone through laboratory and experimental-industrial tests. With the technology available, relying on seasoned scientists and engineers of research and design institutes, and institutes of chemical technology, if we will produce the necessary equipment and reagents, we will be able in a very short time to create industrial technology for mining gold deposits on site, with subsequent processing of industrial products in hydrometallurgical plants of the sector up to the production of refined gold.

The Conversion Program has set the Priargunskiy Mining-Chemical Combine the task of assimilating production of molybdenum and tungsten. One of the main directions of the

work of this combine and the Zabaykalskiy Mining-Enrichment Combine is complete satisfaction of requirements of the sector for fluorspar goods with output of the corresponding industrial products. Tasks that are just as important for carrying out the Conversion Program face the Leninabadsk Mining-Chemical Combine, which is to assimilate the development of small gold ore deposits, and organize the extraction and production of tungsten and vanadium both by underground working, and by the method of underground leaching. Our sector, which is a pioneer in development of scientific-technical principles of underground leaching of uranium, and in industrial and commercial technologies for extraction of other metals by underground leaching, has continued to perfect this technique, and has already assimilated extraction of such accompanying components as scandium and vanadium.

It should be mentioned that the Main Administration is now considering the question of organizing an association for production of facing and semiprecious stones by working deposits of granite, gabbro, listvinite and limestone. Under conversion conditions, this production is highly effective and profitable. Unfortunately not all combines have deposits of natural stone that might be worked, and most importantly, they lack equipment. These problems must be solved, perhaps even by purchasing such equipment from abroad, and also by making it at machine repair plants.

An important direction of conversion of the raw material base of the sector is machine building. At the present time, this subsumes both mining machinery, the production of equipment for the agroindustrial complex, and household appliances. In mining machine building today, we have comparatively progressive projects; several models of mining equipment have already gone through industrial tests, including new loading-delivery machines and drilling equipment. Last year, a sector-wide conference on problems of mining machinery was held with participation of representatives of the USSR Ministry of Metallurgy and Glavalmazzoloto [Main Administration on Diamonds and Gold] who are interested in obtaining this equipment. It has now been decided that the Priargunskiy Mining-Chemical Combine will supply such machines to "Severovostokzoloto" Production Association.

The Conversion Program calls for production of consumer goods and equipment for the agroindustrial complex; enterprise representatives will be talking about this.

In connection with the sharp curtailment of uranium mining, the sector has lately been faced with especially urgent tasks of eliminating some enterprises, and reclaiming and restoring some areas disrupted in the process of production activity. Until recently, problems of this kind were not especially acute, and therefore we are experiencing some difficulties in connection with the work ahead of us, but we still have adequate forces for surmounting these difficulties. For these purposes, a specialized laboratory has been set up that deals with questions of reclaiming dumps, cleaning mine water and radiation rehabilitation of territories. No less important is the reclamation of all tailing dumps, including those that have been retired for a long time. This intricate problem will require

considerable capital investments for successful solution. In this regard, while capital investments for such purposes were previously made centrally, beginning in 1991, enterprises will be working solely on production proceeds. To make the urgency of the situation clear, let me say that we are building and expanding high-profitability enterprises on credit alone.

For successful solution of all the aforementioned problems, we need a Soviet Law on Conversion that would apply to all sectors of the defense industry, and answer questions on preferential allocation of funds for doing all work on conversion.

In this presentation, I have done my best to give a very brief outline of our difficulties. Clearly, the representatives of combines will go into more detail on these issues. We have some good developments in open-pit and underground mining, and underground and heap leaching of ore. There are several progressive proposals that could be introduced in other mining sectors of the national economy.

I would like to wish success to the participants of this "round table," during which the representatives of our sector might learn of what is available to other mining sectors of the nation, in order to make use of these advances in working deposits that are located in our sector of industry.

**GORNYY ZHURNAL:** "Do you feel that your ministry can interact with institutes of the Academy of Sciences and with other ministries? How realistic is the idea of such an association?"

"Until recently, we have looked to our own institutes for the solution of our problems: the All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology, and also the All-Union Scientific Research Institute of Chemical Technology, which are based in Moscow, and comprehensively solve problems of working deposits, construction of mining machinery, and ore processing technology.

"However, this does not preclude the involvement of other institutes in solution of our problems. For example, we have had occasion to meet with the President of the Kyrgyzstan Academy of Sciences I. T. Aytmatov. We talked about calling upon institutes of the republic's Academy for the solution of certain problems. For example, Kyrgyzstan is interested in developing several gold deposits. Naturally, before approaching the question of building large mining enterprises, we would deem it necessary to conduct a thorough scientific, engineering and ecological workup of all issues of mine operation with the participation of institutes of the USSR Academy of Sciences and the Academy of Sciences of Kyrgyzstan."

**GORNYY ZHURNAL:** "Under the conditions of conversion, how are enterprises of the sector to utilize their scientific-production potential, retain skilled personnel, and choose the most effective direction for reprofiling of production?"

The experience of enterprises that have solved, are solving, or are looking for ways to solve these problems will certainly be of interest to readers of this journal. We give the floor to representatives of enterprises of the sector.

**V. F. Zaytsev**, chief engineer of Priargunskiy Mining-Chemical Combine.

In connection with curtailment of State contracts with our combine for natural uranium, there has been a reduction in volumes of extraction and primary processing of uranium ore, and the construction of new mines has been put on hold.

In this difficult situation, the combine has decided to maintain the level of commercial production, and make a profit by finding new ways to take maximum advantage of the powerful scientific-production potential that we have created.

Our priority areas have been: reprofiling the released capacities of the hydrometallurgical plant (HMP) for processing new kinds of mineral raw materials in the national economic category, setting up new mining facilities in the region for extracting these raw materials in explored complex deposits, and also loading free capacities of the HMP with concentrates from mining enterprises of the Trans-Baykal and the Far East.

Based on domestic market forecasts and an agreement that has been reached with enterprises of Glavalmazzoloto, one of the chief measures is to be processing of gold-containing concentrates with production of high-purity gold and silver.

Noble metals are to be extracted from concentrates by using hydrometallurgical technology, establishing the first phase of production in shops of the existing plant. However, expansion and partial reconstruction of the plant will be required to handle the entire volume of possible concentrate shipments.

At the same time, it has been decided to use the hydrometallurgical plant in organizing processing of roasting residues of the sulfuric acid plant at the combine. A long-range program is in the works for using pyrite concentrates at the sulfuric acid plant. The plan for hydrometallurgical processing of roasting residues will yield cementation copper and copper vitriol, iron oxide pigment, zinc oxide and noble metals. On the second phase of plant reconstruction (following introduction of the gold-processing complex), a program will be carried out for producing phthalocyanine colorants based on copper phthalocyanine obtained from processing of roasting residues.



During the entire existence of the combine, an important product has been ammonium paramolybdate extracted from complex uranium ores. To enhance the overall profitability of the enterprise, it has been decided to make molybdenum disulfide from the paramolybdate, and to use this as a basis for making antifriction additives for engine and transmission oils.

Curtailment of the extraction of molybdenum ores has brought the problem of providing the plant with uranium-molybdenum ores, which has prompted the search for new raw sources of molybdenum.

As a whole, the program of conversion of mining-metallurgical production alone will require considerable capital investments in 1991-1995 that will be completely paid back as early as in 1996. But in our present situation of production decline, we are experiencing financial difficulties in carrying out our assigned tasks. Therefore, it is my opinion that highly effective conversion programs should be funded from centralized sources of the Soviet Union and the Russian Federation, bearing in mind that the results of conversion will impact primarily on improvement of the economic and social situation of the eastern region of the republic.

Having based the Conversion Program on the principle of rational utilization of acquired mining-chemical capacities, the combine continues to develop output of goods for the national economy and consumer use. Particular mention should be made here of the organization of production of machines and equipment for the mining industry.

The PD-2EK electrohydraulic rigid-frame machine with load-carrying scoop was made at the combine in 1990 in cooperation with NIPIgorsk [not further identified]. This machine was based on the PD-1P machine that was also made and operated at the combine.

The machine repair plant has begun production of PD-2E electrohydraulic load-hauling machines with load-carrying scoop and articulated frame of NIPIgorsk design.

Plans call for 1991 production of 25 MPDN-1M and PD-2E machines for Glavlamaz-zoloto mines. In addition, NK-12KV blowers are being made for air-coursing mines, and the 2KV-S mobile drill rig designed by our combine is being made for boring vertical shafts 1.5-1.8 m in diameter from the surface to a depth of 160-200 m. The 2KV-S rig can drive 600-700 m of raises per year.

The machine repair plant of the combine is making RS-250 and RS-320 hole reamers, pneumatic chisel setters, hole diggers for shaft reinforcement, car feeder conveyors, pumps and other mining equipment.

The main problem in developing the machine building base of the combine is equipping shops with up-to-date metalworking machines.

Another direction of the machine building program of the combine is producing machines for the agroindustrial complex. Machine building production in 1991 will exceed 11 million rubles.

Mining production in uranium mines of the combine is based on systems of working with hardenable packing, ensuring the greatest efficiency and safety of underground mining. But preparation of hardenable packing requires more than 100,000 metric tons of cement per year, which is creating some complications, as cement is generally in short supply. The combine has decided to build its own cement plant. Planning of the plant is in progress, equipment has been ordered, and the first phase is to be started in 1993.

When running at full capacity in 1994 (200,000 metric tons per year), the plant will completely meet the cement needs of the combine and nearby rural areas, considerably accelerating social development.

An important measure for development of the mining industry of the Trans-Baykal has been transfer of the production forces of the combine's Mine Construction Trust to building and reconstruction of complex mines of the Nerchinskiy Combine and "Zabaykalzoloto" Production Association.

No less important for the area has been an increase in the capacity of the Krasnokamenskiy TETs [heat-and-electric supply station], which has been made possible by intensive development of the Urtuysk power-generating coal fields. The mine is located 15 km from the TETs, and in 1995 will completely meet the coal needs of nearby territories in the region.

An important place in the combine's Conversion Program goes to the production of zeolite goods organized on the basis of the Shivyrtuysk zeolite tufa deposit. A mine with capacity of 200,000 metric tons of raw material was put into operation here in 1989, and a zeolite concentration mill has been built. The range of zeolite products includes fractionated zeolites for agricultural production, cleaning powders and pastes, catalysts, modified zeolites for drying natural gases, and so on.

In 1989–1990, the combine successfully developed economic ties with the People's Republic of China by shipment of goods from the machine repair plant and woodworking combine. Workers were able to obtain a large supply of commercial products and foodstuffs from China on a barter basis.

In addition to the aforementioned provisions of the combine's complex conversion program, a number of minor jobs are also being done, among which we might mention: production of lime, plastic items, household utensils, gardening tools, and so on.

While having difficulties in funding large-scale provisions of conversion, the combine is meeting the aforementioned commitments by specified deadlines by improving the

efficiency of basic production, reducing production expenditures, cutting secondary disbursements, and bringing in money from other Soviet ministries, but completion of the increasing volumes of construction and millwright work in 1991-1995 is threatened without the assistance of centralized funding.

We feel that the concept of conversion development assumed by the combine based on new ways to take maximum advantage of the available mining-chemical plant with developed infrastructure and staffed by highly skilled specialists is most nearly optimum in the present situation.

This will enable us to produce competitive new forms of goods in a market economy, and on this basis provide for the necessary social guarantees of the working force.



**Yu. M. Proshin**, subdivision chief, Mining Department, USSR Ministry of Metallurgy.

"Vitaliy Fedorovich, you have been talking about developing and producing machines and equipment for the mining industry. Do you mean small-scale complexes?"

**V. F. Zaytsev:** "Including small-scale. We are merging to produce a number of machines in the sector. Today our main thrust is on a loading machine with electric drive that we have already finalized. This year we will be making a diesel version. A perforator, a terrific one, has been made by our colleagues from Stepnogorsk, and a track-mounted drill has been developed in cooperation with the Kirgiz Mining Combine. They are already in production."

**GORNYY ZHURNAL:** "Your plant is making single models of equipment; can this equipment be produced on order for other enterprises, and if so, how many?"

**V. F. Zaytsev:** "We have a co-op. We are making equipment today for related enterprises, but the situation in the ministry is such that underground mines are being phased out, and our enterprise is practically the only one left that is working low-capacity ore bodies. Our requirement for such equipment is about 50-60 machines, and we are ready to sell 15-20. In future, our program provides for production of 60-70 machines per year. For this purpose, construction is being completed on a shop with production area of 5,000 m<sup>2</sup>; but before we can talk about series production of these machines, we will need equipment. Therefore, we are interested in the participation of supporting organizations; Glavalmazzoloto is already doing this. We invite the USSR Ministry of Metallurgy to take part as well."

**GORNYY ZHURNAL:** "The current situation is characterized by complete destruction of vertical connections, labor productivity is declining, the percentage of completed agreements is inadequate. In your opinion as a production worker, do we need some kind of center that coordinates horizontal connections among different mining sectors?"

**V. F. Zaytsev:** "In general, I am not in favor of large associations: I feel that the most correct course is the one that we are now on. Mutual interest has been demonstrated in joint operation with Glavalmazzoloto, and we are handling our problems with enterprises of the territory by concluding agreements. In my view, this approach is more acceptable than setting up large associations. With regard to coordination work: perhaps our meeting today is coordination of that kind. We congratulate GORNYY ZHURNAL for such coordination work."

**Ye. N. Kamnev**, chief of the division of scientific and technical information, All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology.

**"How is conversion proceeding from the standpoint of expanding foreign trade ties with China, Korea and Japan?"**

**F. V. Zaytsev:** "Barter trade ties with China are being rather extensively used, and will be expanding. To some extent, we are intermediaries for other combines in the sale of fertilizers, we have concluded agreements on transmission of some electric power. Talks are in progress with some companies of South Korea for expansion of mutually advantageous trade."

**V. M Kirpichenko**, deputy chief of scientific-technical department of "Rudprom" Concern.

**"What do you propose specifically for other enterprises and sectors? We understand that you may be oriented toward small loading machines; can you seriously talk about self-propelled combines? What more can your combine suggest for the domestic market?"**

**V. F. Zaytsev:** "We will be able to produce self-propelled combines, but first, contracts are needed. These issues must be handled on the sector scale, and they are solvable. I am glad that representatives of other sectors of the mining industry have shown an interest in our technologies. We have excellent technologies for underground and heap leaching. We deal with uranium, are working out questions of leaching gold, and will expand the areas of application. We can transfer this technology by agreements. Our technology for underground mining (horizontal layers with packing, work under concrete) are being used here and there in the development of nonferrous metal deposits, but we have raised this technology to perfection, including monitoring the quality of packing. Our electrometric monitoring method is most effective."

**V. M. Kirpichenko:** "Vitaliy Fedorovich, don't you think that it would be worthwhile to return to the oxidized molybdenum ore co-op?"

**V. F. Zaytsev:** "The All-Union Institute of Chemical Technology is now developing autoclave technology for extracting oxidized molybdenum ores."

**F. I. Pasechnik,** chief geophysicist, Tselinnyy Mining-Chemical Combine.



At our combine, the conversion of processing plants and corresponding reconstruction is proceeding in three directions:

1. Processing of gold-containing raw material (roasting residues of our own sulfuric acid production, Leninogorsk pyrite concentrates, rush arsenopyrite concentrates and ore of some Kazakhstan gold deposits) to obtain refined gold. In this direction, cyanide compounds in liquid wastes are being rendered harmless by a fundamentally new technological process: autoclave thermal oxidation.
2. The sulfuric acid plant is being converted to a new type of sulfur raw material: sulfide concentrate obtained from the enrichment tailings of Sokolovsko-Sarbayskiy Mining Enrichment Combine. Nonferrous metals (cobalt, copper, zinc) will be concurrently extracted from pyrite roasting residues of sulfuric acid production, and filtered enrichment tailings will be routed to ferrous metallurgy enterprises as raw material for steel production.
3. In cooperation with Chelyabinsk Metallurgical Combine, a feasibility study is being done on processing sulfide-molybdenum concentrate at Tselinnyy Mining-Chemical Combine with output of goods meeting requirements for production of ferroalloys, and utilization of useful components from waste gases.

Mining subdivisions of the combine are assimilating the extraction of mineral raw material resources of Northern Kazakhstan that are new to them: tin-containing ores, natural industrial diamonds, facing stone from deposits of intrusive and sedimentary rocks; a tungsten deposit has also been added to the balance sheet of the enterprise, but its assimilation is being delayed due to lack of a State contract. In this context, we should not fail to mention the problems now being encountered by the enterprise in allocation of lands for assimilation of new deposits. The delay in ratification of a Law about Conversion, and the lack of clear legislative acts to regulate compensation of expenditures and outlays for socioeconomic development of the area of the deposit to be assimilated, allows the regional agencies to make a decision either disallowing allocation of lands, or allocating them under such conditions that development of the deposit becomes unprofitable. All of this is happening in our territory. And this is leading to ineffective utilization of the potential of the enterprise, impeding conversion processes, and delaying assimilation of the raw material base of the region and its socioeconomic development.

Conversion of the mining complex of the combine accompanied by retirement of main production deposits, and increasing demands for environmental protection have exposed some ecological problems involving removal of abandoned mines and reclamation of destroyed lands.

Previously developed plans by which deposits have been worked did not deal with issues of cleanup and reclamation, and accordingly no fund was formed for financing future expenditures for these specific purposes. Generalized estimates show that these expenditures for the combine will amount to 70 million rubles. The head planning organization has been commissioned to draw up design documentation on the entire work package. The large volume of these jobs and the lack of funds at our enterprise have made it necessary to incorporate them into the sector-wide conversion program.

Funding of these expenditures should be provided both in plans for reconstruction of existing enterprises of the combine, and out of the special fund for conversion assistance (with respect to eliminated subdivisions of the combine). We must accelerate agreement and confirmation of new Sanitary Rules for removing, retiring, and reprofiling enterprises in extraction and processing of radioactive ores, as these jobs cannot be planned and carried out by the old rules.

There needs to be a reworking of sector-wide standards on classification of solid wastes, and the use of rubble prepared from them in construction, and also on the classification and utilization of mine water, bringing them into strict accord with the latest edition of Radiation Safety Standards (NRB—Normy radiatsionnoy bezopasnosti) and Basic Sanitary Rules of Working With Radioactive Materials (OSP—Osnovnyye sanitarnyye pravila raboty s radioaktivnymi veshchestvami).

**GORNYY ZHURNAL:** "We were told earlier that your enterprise produces hydroperforators. Tell us more about this."

**V. N. Fanshteyn**, chief mechanic, Tselinnyy Mining-Chemical Combine.



Our combine has been making hydraulic perforators for more than 10 years. During this period, we have made and tested more than 20 modifications of prototypes and experimental models of perforators of the GP series. The developers of perforators of this series are KarPTI [not further identified] and the Central Scientific Research Laboratory of Eastern Mining-Enrichment Combine.

Currently working with us as a developer is the "Norit" Scientific-Technical Center based on KarPTI specialists.

In 1988, we began shipments of hydraulic perforators made by a special shop of the combine's machine repair plant (practically beginning series production) on consignment. Technical specifications, facts about classification and modification of GP series being produced can be found in an advertisement on the back of GORNYY ZHURNAL. Production output by years is distributed as follows: 1988—30 packages, 1989—80, 1990—191, and in 1991 we plan to produce 175 packages.

At the present time, our capacity for producing hydraulic perforators is limited to 200.

We have been helped in reaching the level of series production by the form of cooperation with "Norit" Scientific-Technical Center. The center has assumed the responsibility not only for long-range development of the design, but also the solution of ongoing problems involving change of components, and perhaps most importantly, has accepted the obligation of on-site servicing of hydroperforators. With the volume of hydroperforators that we produce, it would be beyond the capacity of the plant to maintain structures for support of the aforementioned functions.

The main customers for our perforators in 1990–1991 are Kuzmashzavod (70 packages), Soyuzgidrospetsstroy (20), "Prokopyevskgidrougol" Production Association (10), and "Krivbassruda" Production Association (20 packages).

Some enterprises are installing the perforators on their own imported hydraulic drill rigs and jumbos, where the service lives of drill heads have expired (Shalkiinskiy RU, Chirkeyskiy SU, Achinskiy SU, and others). "Norit" Scientific-Technical Center is of great assistance in solving problems relating to adapting the Soviet hydroperforators to imported equipment.

Other contractors for hydroperforators in 1990 and 1991 are industrial institutes working on development of mining equipment (TsNIIPodzemash, NIPIgormash, VNIPInrudmash, KuzNIIshakhtstroy [expansions not given] and others).

However, analysis of use of the perforators that we have produced shows that mining-enrichment combines and mining machinery enterprises today are not ready to take even the volume of perforators that we are capable of producing. Considering that Kuzmashzavod is going straight into series production of hydraulic jumbos using the GP 101, and assuming that only some of the developers of head industrial institutes will favor the use of series GP hydraulic perforators on drilling equipment, it can be expected that beginning in 1992, the demand for these perforators will considerably exceed the capacity for producing them. Consequently, in parallel with expansion of the production of Soviet hydraulic drill rigs and jumbos, a solution must be found for the problem of increasing the production of series GP perforators. Unless enterprises (potential customers) are connected with the solution of this problem, there will be no solution.

The production of hydroperforators can be increased after reconstruction and expansion of the perforator shop of the machine repair plant at Tselinnyy Mining-Chemical Combine. We feel that we can realistically bring the annual production of GP series hydraulic perforators to a level of 1500-2000. However, these volumes require refinements based on calculation of complete satisfaction of demands of the domestic market. "Norit" Scientific-Technical Center is now studying the long-range demand for hydraulic perforators.

Our enterprise may undertake the solution of this complex problem if interested enterprises and agencies will provide maximum assistance, including funding.

It seems advisable to me to take the following course in practical realization of the task of expanding hydroperforator production:

determination and summation of annual monetary expenditures by enterprises of various agencies on acquisition of hydraulic perforators and hydraulic equipment that uses such perforators;

determination of the possibility of using the GP series instead of imported hydroperforators, and as a result of this substitution freeing up cash to expand the production of Soviet hydraulic perforators;

under guarantee of future deliveries of hydraulic perforators, concluding a multilateral agreement (other forms are possible as well) on shared participation in funding the expansion of hydroperforator production. In addition to the guarantee of future deliveries, enterprises signing the agreement would receive hydroperforators being produced by us at existing capacities, enabling them to prepare all components of their production facility for their most effective utilization.

An interagency expert commission would have to be set up to analyze the economic feasibility of our proposal. The commission would be able to consider and compare other alternative proposals and options.

The basis of our proposal is that the old production and administrative ties are practically not working today, and there is no market. Therefore, we must now find a method of attracting the interest of enterprises that might assume the responsibility of organizing production of new mining equipment. This interest can be materialized and realized only by the unified efforts of future customers for this equipment. What is needed is definitely economic interest, i.e., an enterprise, in extending us interest-free credit and transferring funds for certain materials and equipment, has to be certain that this is more profitable than constructing new production facilities in-house.

**GORNYY ZHURNAL:** "In his report, V. F. Zaytsev brought up the question of cooperation with foreign companies. How do you see the outlook for your own enterprise?"

**V. N. Faynshteyn:** "Such cooperation is necessary, but in my opinion it is hopeless because of our internal problems.

"The 'Vismut' Company has started production of small truck-mounted drills, and we were supposed to produce light hydraulic perforators for them, but as of now, these plans have not been carried out. I can say the following about our interest in contacts with foreign companies. Today, in order to approach the question of series production of hydroperforators in the Soviet Union, we must solve the problem of equipping the plant. Right now, the USSR has no up-to-date grinding equipment. Moreover, there is a drastic deficiency of precision measurement instrumentation, by which I mean comprehensive laboratories. Having made unsuccessful attempts to obtain the necessary equipment inside the Soviet Union, we have decided to find foreign partners. Of course, the best guarantee is to set up joint production."

**Yu. M. Proshin:** "I would like to express my opinion about the problem of mining equipment production. The USSR Ministry of Metallurgy is the biggest "company" in the world in the mining of minerals, iron ore, and nonferrous ores, both with respect to volume, and with respect to number of workers. The most urgent problem, whose solution will decide the fate of further production development, is to provide mine enterprises with mining equipment. The production of this equipment is the province of the USSR Ministry of Heavy Machinery, and we rely on its work."

"Our mining enterprises are only 60-70% equipped. The quality of this equipment is far below world standards. We have almost no capacity for equipment production. As I understand it, the mining enterprises of the USSR Ministry of Nuclear Engineering and the Nuclear Power Industry are developing equipment and producing it in their own machine repair plants. Of course, we probably will not invest money in the development of such equipment, as Glavalmazzoloto is doing. We would like to train our sights on the freed capacities of ministries of the defense complex and nuclear engineering."

"Right now, one of the biggest plants that produce equipment for the defense industry is setting up an association for the production of heavy drilling rigs, and all without capital investments of our ministry. We would like to go out with similar proposals to the enterprises whose representatives are assembled here.

"We do not have a great need for small flitting machines. We need machines for large enterprises with bucket capacity of 2.5 m<sup>3</sup> or more. We have been talking to enterprises of your ministry for some time now, but still have no contacts. We need machines that meet GOST standards and our own specifications. We have offered to test hydro-perforators, underground freight elevators and flitting machines with the participation of our institutes in our mine or yours. On the basis of such tests, we could conclude agreements and start producing this equipment, or decide whether to buy it from your enterprises. Perhaps the speakers might answer the question of how we could develop these contacts further.

"And one more thing. Your enterprises are using plastic pipe. I would like to learn where to get it, and whether your enterprises can arrange to produce such pipe. We need hundreds of thousands of meters. So far we have not been able to locate such a producer."

**GORNYY ZHURNAL:** "What are the main directions of reprofiling of production in the framework of conversion of the 'Priklaspiyskiy Mining-Metallurgical Combine' Production Association?"

**B. A. Zavyalov,** deputy director of mine No 5, "Priklaspiyskiy Mining-Metallurgical Combine" Production Association.

I will discuss the problem of organizing the production of building materials and manganese concentrate; such are the directions of reprofiling of our enterprise.

The curtailment of production volume at mine No 5 is resulting in a systematic layoff of workers who have considerable work experience, and are at the most employable age. In approaching the problem of reducing the mining staff, we have been cooperating with scientific research institutes and the Central Scientific Research Laboratory in looking at the possibility of organizing a mine-based enterprise for producing building materials.

Research by Alma-Ata NIIstromprojekt [not further identified] has determined that the paleogenetic clay covering the rock of the mine has a material and chemical composition that makes it a unique raw material for production of ceramics.



It has been established that this raw material is suitable for producing expanded-clay gravel and roofing tiles; specimens made from it have indices corresponding to GOST standards. The Central Scientific Research Laboratory of the association has done research and developed technology for producing facing tiles; in addition, experiments have been done on producing foam glass from the clay.

Research results have confirmed the feasibility of constructing a plant based on mine No 5 for producing expanded-clay gravel, facing tile, roofing tile and foam glass.

Analysis of the current and future level of supply of porous filler materials to Guryevskaya Oblast has shown that the existing production facility working at full capacity cannot meet the demand for this material. Nor is it possible to make up the shortfall by bringing in material from neighboring oblasts of the republic because of their lack of surplus capacities.

NIIstromprojekt has now developed a plan for construction of a plant to produce expanded-clay gravel (all working drawings to be delivered before the end of the year). The plan provides for engineering-technical and social support of the plant by the existing services of mine No 5, so that no provisions are made for construction of a boiler house, repair machine shop, administrative and domestic combine, cafeteria, or quarry, and there is no need to acquire transportation, conveying facilities, or mining equipment. All this considerably reduces the cost of plant construction.

A nice feature of the plan is that boiler furnaces are used as the main kilns, reducing the process fuel requirement by 35% as compared with the conventional method of producing expanded clay in rotary kilns.

The chemical and material composition of the clay in the mine is suitable for production of foam glass for construction. In the combine's Central Scientific Research Laboratory, glass was melted under laboratory conditions from the following charge: 90% mine clay, 10% quartz-glaucite sand (the overburden of the Mangyshlak manganese deposit. The melt was made in a muffle furnace at a temperature of 1500°C. The result was a product suitable for making foam glass. The glass is dark brown, probably because of the vegetative residue in the clay (up to 5%).

The specifics of the structure and the thermophysical properties of the foam glass put it into the ranks of modern insulation materials. An important advantage of the foam glass over some natural and artificial materials is its inorganic composition and low water absorption. This makes it highly resistant to rot, microorganisms, the action of high temperatures (up to 500°C) and most chemical reagents.

The main field of application of construction-grade foam glass is for insulating components of housing and industrial buildings and structures, process equipment used

under conditions of natural cold, at high temperatures, and elevated humidity, for thermal insulation of hot surfaces and heating units: furnaces, driers, reaction towers and the like.

The production cost of 1 m<sup>3</sup> of foam glass is 22.8 rubles, of which 7.47 rubles (32.8%) is the cost of the material. With inexpensive raw material at the mine, the production cost of 1 m<sup>3</sup> of foam glass could be reduced by 15–20%. With a plant capacity of 100,000 m<sup>3</sup> per year, assuming a wholesale ex-factory price of 59 rubles/m<sup>3</sup>, the output of marketable goods is 5.9 million rubles, and an additional 7,000–8,000 m<sup>3</sup> of crumbs could be sold at a price of 17.4 rubles/m<sup>3</sup>. The total volume of salable goods would be 6.04 million rubles per year with expenditures of 2.28 million rubles, giving a profit of 3.76 million rubles. There would be a staff of 150 employees.

The combine's Central Scientific Research Laboratory has developed technology for producing facing tile using clay of mine No 5, the best results being obtained with a charge containing 40–50% clay and 60–50% keramzit (dehydrated clay). Semi-industrial tests have shown that the resultant tile meets GOST requirements, corresponding in quality mainly to grades II and III, and only 10% corresponding to grade I.

Before starting design of the plant, the developed technology has to be checked out under industrial conditions.

The necessary samples of clay, keramzit and limestone will be sent to the State Scientific Research Institute of Building Ceramics in the immediate future.

Agreement has been reached with the planning and design office of the State Scientific Research Institute of Building Ceramics about development and delivery of working drawings by the end of 1991 on construction of a plant for producing facing tile with a capacity of 1 million m<sup>3</sup>/year.

According to designers, the estimated cost of the plant will not exceed 3.0 million rubles, which includes 1 million rubles for equipment.

Calculations of the output of salable goods of the plant with respect to the production of tiles, as well as consolidated calculation of the production cost of tiles shows a definite advantage to construction of such a plant: with a production output of 13.6 million rubles, the profit from 1 ruble of expenditures is about 7 rubles, and moreover there is the possibility of selling products to the population in a volume of 3–4 million rubles per year as consumer goods.

In recent years, the quality and quantity of manganese concentrates produced in our nation have noticeably declined due to a reduction in the reserves of high-grade oxide ores and an increase in the percentage of the total extracted volume of carbonate and oxidized ores that are of a lower grade and are more difficult to concentrate by conventional

methods. Of interest in this connection is development of the Mangyshlak manganese deposit that is located 60 km from mine No 5.

The deposit is represented by tabular beds of manganese concretions in quartz–glauconite sands covered by sand, loam and limestone to a thickness of from 1 to 40 m. The predominant ore type is oxide. The concretions are sandstone formations on manganese mineral cement. This has made it ineffective to use conventional methods of enrichment, and has put the reserves of the deposit in the extra–balance category.

Laboratory studies done by the Central Scientific Research Laboratory of the enterprise have established the possibility of obtaining high-quality manganese concentrate by chemical enrichment based on leaching manganese from the oxide raw material with sulfur dioxide.

A process arrangement has now been developed for obtaining manganese concentrates by using sulfur dioxide produced at the sulfuric acid plant of the enterprise.

The manganese content in the concentrate is 64–69% with 92–95% extraction from the ore; phosphorus content does not exceed 0.01%.

Putting the manganese deposit into service will yield about 60,000 metric tons of high-quality manganese concentrate per year with high economic indicators, employ about 350 workers, and utilize idle mining equipment.

**D. P. Lobanov**, chairman of geotechnology department, Moscow Institute for Geological Exploration.

"This enterprise has a wealth of experience in hydraulic borehole mining. The collective was one of the first to introduce this technology first in one mine, and then at mine No 5. An experimental industrial complex has been set up with a complete infrastructure. But unfortunately, since the uranium program has had to be phased out, and the path to conversion taken, this unique facility has not been completed, and it has remained unemployed. But it should be brought back to life. There are a number of useful minerals in this territory: manganese, diamonds, gold. The enterprise has a great wealth of experience in working deposits by hydraulic mining, and it should be used."

**GORNYY ZHURNAL:** "As we know, our nation gives a lot of attention to problems of radiation safety. How is this issue being addressed in the territory of uranium mining enterprises?"

**Yu. N. Soroka**, candidate of technical sciences, senior scientist (Ukrainian Affiliate, All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology).

Some uranium mining enterprises will be eliminated in connection with conversion. Transfer of these enterprises to the national economy requires work to ensure radiation safety on their territories. The industrial laboratory of environmental protection of the Ukrainian Affiliate of the All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology has fifteen years of experience in successfully dealing with the problem of normalizing the radiation situation on the territory of uranium mining enterprises and in their environs. The main areas of research are: effective utilization of solid wastes, controlling dust on the dry beaches of tailing dumps, and reclamation of destroyed lands at mining and processing enterprises.



Mining and processing wastes at uranium enterprises contain mostly elevated contents of natural radionuclides. Uncontrolled use of these wastes may lead to radioactive contamination of separate territories, and even residences, and in some cases this has already happened. Such situations have occurred in Ozernyy, Zheltyye Vody, Krasnokamensk and some other towns of Soviet Middle Asia. In addition, such a situation is typical not only for "uranium towns." For example, in Akchatau, Kazakh SSR, where tungsten miners live, some houses have an abnormally high radon level. This is because of the high content of natural radionuclides (NRN) in building materials. Increased NRN concentrations are typical of deposits of tungsten, molybdenum, iron, lead, zinc, titanium, bauxites, phosphorites, and some rare-earth elements. A sector-wide standard is now being developed in which all wastes are divided into three classes of radioactivity.

Closer attention to dust is in prospect due to the drastic increase in fines for dusty emissions. A technique has been developed for stabilizing dusty surfaces by adding binders to the general mass of wastes during transport. A technique for explosive packing of wastes has passed experimental industrial tests.

When wastes stay on the surface of the ground for a long time, natural radionuclides and heavy toxic metals are leached from them, causing contamination of the surrounding territory. A major factor of impact on the environment is liberation of radon from the surface of spoil heaps and tailing dumps, decay in the atmosphere, and contamination of adjacent territory with  $^{210}\text{Pb}$  and  $^{210}\text{Po}$ . Technology has been developed for reclamation of radioactive waste spoil heaps and tailing dumps that allows not only for the aforementioned specifics, but also for general requirements of reclamation. The introduction of order into issues of utilization of land resources, and the drastic increase in prices for allocation of lands is making it necessary to use the territories of industrial sites of mining enterprises for construction of industrial enterprises and housing. In some cases, there are considerable emissions of radon from the soil in these areas, which is fraught with an increased radiation load on personnel and the populace. Radon exhalation from the surface of the ground exceeding the background levels in the area has been observed on

the territory of the industrial site of the uranium mine in Zheltyye Vody. Values of exhalation have been measured in the same area on a retired iron ore tailing dump that is destined for housing construction. They reached  $70\text{--}100 \text{ mBq}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , which is 3-5 times the background level. When buildings are erected on this territory, there will be elevated radon concentrations in residences, and in this regard it was decided to drop the development project. After the necessary reclamation has been completed, it might be possible to turn this territory into a park.

Another serious problem now emerges when reclaiming retired sites: contamination of the environment in the vicinity of mining enterprises with toxic and heavy metals, among them cadmium, selenium, molybdenum, tungsten, arsenic, mercury, lead, and others. Especially serious attention should be given to determination of the parameters of contamination, and development of methods of toxic waste disposal that are safe for the future.

Even in the design stage, there must be rigorous analysis of the possible consequences of mining a given region, and steps must be taken to protect the environment and pick the most unintrusive technologies for mining and processing ore.

**GORNYY ZHURNAL:** "Mining enterprises of your sector are working intricately structured deposits by the open-pit method. This valuable experience may be of use to miners of the USSR Ministry of Metallurgy as well. What are the prospects and possibilities for cooperation on this problem?"

A. N. Lukyanov, chief of research department of mining technology problems in open-pit development of mineral deposits, All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology.



Minerals are worked by the open-pit method in the sector mainly in accordance with evolved Soviet practice. Distinctive features of intricately structured deposits of the sector are the steep dip of appreciably branching ore bodies at an angle from 60 to 80°, low metal content in the ore (kilograms and grams per metric ton of ore) and high variability of content with respect to the area of ore bodies (100-150%). Because of this complicated structure of ore bodies, it has been necessary during mining work to use selective blasting and excavation of ore bodies on low terraces, which has dictated the use of low-power equipment with low productivity. At the same time, working a gold deposit of major proportions like Muruntau has required the development and introduction of new programs to determine the boundaries of the mine, the optimum direction for increasing depth, and conditions for doing mine work on the level of the "pit" subsystem. New technological processes have been worked out on the level of the "working zone" subsystem, including primarily employment of SBSh-250MN

high-productivity drill rigs with the use of bottom collar shock absorbers with axial loads on the bit of 200–240 MPa at a frequency of rotation of the drill rig of 2–2.5 m<sup>-1</sup> and compressed air discharge rate from 0.41 to 0.53 m<sup>3</sup>/s, giving a driving rate of 200 m/shift and productivity of 60,000–65,000 m/year.

Blasting of ore benches has been done by a method that retains the geological structure of the massif with the use of at least six rows of holes 12–17 m deep in a grid of 8×8 m. A "cushion" of rock 10–15 m thick from the preceding blast was retained in front of the bench being blasted. As a result, it was possible to get coefficients of loosening of rock in a blast of 1.14–1.18. The blasted ore mass is selectively removed by EGK-8I excavators, and then transported by dump trucks with capacity of 57 and 110 metric tons to an ore storage area located at the edge of the pit.

At the Muruntau mine, the overburden is transported by using cyclic flow technology. The rock mass goes from the dump trucks to crushing and transshipping points or to a stationary screen. Then the overburden rock goes by two open conveyer lifts located on the edge of the pit to main and dump conveyers where an OShS-4000/125 spreader forms the spoil bank.

At the present time, the productivity of cyclic flow technology supports normal operation of the gold processing plant. The increased depth of the pit (now at 250 m) has brought considerable difficulties on the part of maintaining normal ecological conditions of the pit and its edges.

To solve these problems, a taxonometric system has been developed for normalization of the atmosphere in the pit, including mining-geological tasks of optimizing directions of increasing the depth of the pit, upgrading technological processes of drilling, blasting and loading and delivery work, developing methods and means of general-exchange and local ventilation of work sites on benches with the highest level of contamination, and also creating individual means of protection from gas and dust in the cabs of mining machines, developing instruments for monitoring maximum permissible levels of exhaust pollution with processing and transmission of information about the state of the atmosphere in the pit to a dispatcher station.

The principal form of transport in working intricately structured deposits is by truck, which is also the main source of exhaust pollution of the pit. Consequently, a major technological task is to develop methods and means of considerably reducing the number of dump trucks, which must move along horizontal sections of the pit, excluding considerable grades in trenches as far as is possible.

For these purposes, 75-ton dump trucks are being consistently replaced with 110-ton vehicles, reducing the consumption of diesel fuel by 20%. Since unloading of conveyer lifts at transshipment points produces considerable gas concentrations because of the accumulation of dump trucks at these sites, the use of extension conveyers with storage

capacity of 3,000–4,000 m<sup>3</sup> on the flanks of the pit maintains the most rhythmic operation of conveyer lifts which have an hourly capacity equal to the storage capacity of the extension units.

Provisions are made for using chutes with bypass of rocks from a height of 90 m. In the lower part of the rock chutes there is also a unit with capacity of 4,000–5,000 m<sup>3</sup> from which the rock is moved by VTU-8 vibrofeeders to 110-ton dump trucks. Consideration is being given to future use of larger dump trucks (180—250-ton), requiring excavators with 25–30 m<sup>3</sup> scoop capacity, which unfortunately are not produced by Soviet industry at the present time.

The volumes of utilization of dump trucks will decline upon attainment of the design capacity of cyclic flow technology (20–25 million m<sup>3</sup>/year), and also with extensive introduction of diesel trolley cars for transporting rock. Experimental-industrial work on the use of this form of transport is now being done in the mine. Thus, increased load capacity of dump trucks, the use of rock chutes, extension conveyers, movement of dump trucks along horizontal sections as far as possible, the introduction of cyclic flow technology for transporting ore and overburden, and also diesel trolley cars will reduce the consumption of diesel fuel by a factor of 3–3.5.

One way to attain the most complete extraction of ore from deposits is to use the method of heap leaching to extract metal from low-grade ores, which in turn reduces the volumes of ore taken from the mine and the pace of increasing depth.

A second direction in working deposits is stabilization of the edges of the mine and its environs. For this purpose we have determined the limiting angles of repose of terrace banks and the edges of the mine, have developed and introduced technology for shielding the marginal zone from blasting in the mine, have determined the parameters of shield gaps for bench heights of 30 and 45 m, and have redesigned the SBSH-250MN rigs to bore holes to a depth of from 40 to 60 m at angles of 45, 55, 65, 70 and 75° with diameter of 190, 215 and 245 mm. The holes of the shield gap are blasted with hose explosives, and excavation in the marginal zone is done by EKG-4u excavators with extended working parameters.

Research and experimental development are being done in cooperation with scientific research institutes: Mining Institute imeni Tsulukidze, Mining Institute of the Siberian Department of the USSR Academy of Sciences, IGTM, IITM, VNIMI [expansions not given], State Design and Planning Scientific Research Institute of the Nickel, Cobalt and Tin Industry, Moscow Institute for Geological Exploration, Moscow Construction Engineering Institute, Mining Institute imeni A. A. Skochinskiy, and others, and also jointly with production enterprises of the sector.

Since it is difficult to go into details in a brief listing of jobs that are done in working intricately structured deposits by the open-pit method, we would be grateful to anyone showing an interest in teamwork.

**GORNYY ZHURNAL:** "Is anything being done about combined development of the Muruntau mine?"

**A. N. Lukyanov:** "Development of such an intricately structured deposit that is unique in its enormous size and continuously increasing ore reserves requires continual reexamination of technological approaches. The first rough estimates have already been made on working a pit to a depth of 1000 m. In this connection, work is in progress near the edge of the mine, and in future will be done below the bottom level of the pit."

**GORNYY ZHURNAL:** "How much rock can go through a chute during its service life?"

**A. N. Lukyanov:** "A rock chutes passes about 6–8 million m<sup>3</sup> of material per year. The height of the chute is 90 m, subsequently decreasing as work proceeds from the top down."

**GORNYY ZHURNAL:** "What vibrofeeders are used at the transshipment points?"

**A. N. Lukyanov:** "We use 'Volna-8' vibrofeeders designed by the Mining Institute of the Siberian Department, USSR Academy of Sciences."

**GORNYY ZHURNAL:** "What is the effectiveness of cleaning of spent gases when they pass through the rock in the body of a dump truck?"

**A. N. Lukyanov:** "When harmful gases pass through rock, exhaust pollution is cut in half within 5–6 minutes after the truck moves away from the working face, but this is long enough for it to reach the crushing and transshipment point."

**GORNYY ZHURNAL:** "The recent pressing need for a prudent attitude toward natural resources has forced miners to turn their attention to small deposits with a low content of useful components. Underground and heap leaching are being more and more extensively used for working deposits of valuable metals. Your institute has been working with underground leaching for a long time. What is new in this field, and what are the prospects for using unconventional methods of extraction in mining sectors?"

**L. B. Prozorov**, chief of research department of underground leaching, All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology.

For the past 30 years, there has been a burgeoning growth of the method of underground leaching in the uranium mining industry of the USSR. The use of this method has now reached roughly 40% of the total volume of uranium extrac-



tion, and by the year 2000 will exceed 50%. The introduction of this method has allowed us to work with high technical and economic coefficients in developing deposits of epigenetic type where the uranium content is an order of magnitude less than in the ores of deposits worked by underground or open-pit methods.

Among the advantages of the underground leaching method over conventional mining methods are: reduction of capital investments in construction of basic and ancillary facilities by a factor of 3-5; an increase in labor productivity by a factor of 2-3; a high return on capital investments; short time of construction of enterprises (1-2 years); high level of completeness of working reserves, and versatility in working ores; high level of automation of technological processes (at least 95%); pleasant working conditions for production personnel; ecological safety and complete return of underground and surface to land utilization.

In this country, the leaching reagent of preference is sulfuric acid with concentration ranging from 2 to 25 g/l, depending on the stage of the leaching process.

To intensify processes of underground leaching and reduce expenditures on subsurface reclamation, the technology of underground leaching of ores by gas-saturated solutions is being introduced. This technology is based on the principle of increased solubility of uranium when it is oxidized (using oxygen or air) and increased concentration of the complexing agents that bind it in solution (using carbon dioxide).

Special methods of ore preparation are used when working deposits confined to low-permeability thin beds or to multiple-tier protore formations. Among such methods are artificial back-filtration screens that are created by various modifications of hydraulic breakup of a stratum. To intensity underground leaching in low-permeability rock, we are learning to use methods of electromagnetic action on the formation that is being leached.

In working deposits by the method of underground leaching, particular attention is given to ecological safeguards. As the deposit is being worked, the condition of underground water is monitored by observation holes, and the state of the surface is monitored by gamma surveys and radiochemical sampling.

Surface reclamation follows the completion of working of a deposit or a section of a deposit. Several methods have now been developed for cleaning up contamination, among which electrosorption technology (EST) is most extensively used on an industrial scale. This method removes chemical pollutants (sulfates, arsenates, heavy metals) and radioactive contaminants (uranium, radium) from the surface. The time for cleaning sections is up to 30 days, and the cost of reclamation is up to 2,000 rubles per hectare.

Several methods have been developed and have gone through experimental and experimental-industrial testing for cleaning fresh underground water on the edges of



Technology of spraying and collecting process solutions in heap leaching

worked-out blocks. In this context, most promising from the standpoint of technical-economic indicators and scales of application are methods of artificial demineralization of underground water ("broaching" method), replacing contaminated water with interstitial water ("rinsing" method), displacement with compressed air ("displacement" method) and electrosorption (EST method). Some of these methods are used in combination with others to improve the efficiency of cleaning underground water. Depending on the methods, the period of reclamation of underground water is from one or two months to one and a half or two years, and according to estimate data, the cost of cleanup is from 0.2 to 2.0 rubles per cubic meter of water.

Gold mining should be especially singled out among the directions of conversion with respect to introduction of underground leaching methods in the mining industry of the nation. A technology of underground and heap leaching is now being developed for working small deposits with low gold content under difficult geological and hydraulic conditions. In this context, ecologically nonintrusive leaching reagents are being tested.

Laboratory studies on leaching with original reagents have shown that gold extraction reaches 80–95% from samples with low gold content. Leaching time with agitation is up to 36 hours. The ecological safety of the reagents has been demonstrated under laboratory conditions. Based on these studies, a large-scale experiment on a trial section is being planned.

Of interest for the solution of a wide range of ecological problems is a software package developed in the sector (chief developer was the Central Scientific Research Laboratory of Computer-Aided Control Systems of Leninabadsk Mining-Chemical Combine) for estimating and forecasting the ecological situation in regions of working tailing ponds (sludge accumulators), liquid waste storage facilities, and underground leaching installations. This software can determine the concentration of pollutants at an arbitrary point of space at an arbitrary time after starting operation of the facilities, and the dynamics of their subsurface migration as a function of the geological-hydraulic characteristics of rocks, the component makeup of technogenic solutions, the conditions of operation of the facilities, and also provides plotter output of hydroelecological maps of the region to develop natural conservation measures and a monitoring system.

**D. P. Lobanov:** "Has leaching been tried on manganese?"

**L. B. Prozorov:** "Not on manganese."

**D. P. Lobanov:** "No surface settling?"

**L. B. Prozorov:** "None."

**GORNYY ZHURNAL:** "Does our nation have a comprehensive program on developing this kind of work for gold?"

**L. B. Prozorov:** "Kazakhstan has a program for gold, and programs are being developed for Kyrgyzstan, as well as a general program of our ministry, where combines are merging their efforts. Work of exploratory nature is being done for iron."

**GORNYY ZHURNAL:** "The problem of utilizing mine water is an urgent one in territories of operation of mining enterprises of the USSR Ministry of Metallurgy. Now mining is being curtailed. Does your agency have any experience with this problem?"

**V. N. Mosinets:** "We have been approached about this problem. We have suggested what we have done in the sector. We have used methods of electrodialysis cleaning of mineralized water. We can clean as much as 1000 m<sup>3</sup> of water per hour. However, the necessity of capital investments on construction of treatment facilities has not been supported. Our specialists have provided technology, and even with a solution for the problem of getting rid of the dry residue. The technology allows us to obtain biologically clean water. Such a problem does not exist in our sector. There is a parametric series of installations from 5.0 to 100 m<sup>3</sup>/hr: when the total salt content is 12 g/l, the output water contains no more than 1.2 g/l. Cleaning cost ranges from 50-70 copecks/m<sup>3</sup> to 1.5 rubles/m<sup>3</sup>, depending on conditions."

**Ye. A. Kotenko**, doctor of technical sciences, chief of the scientific research department of technological problems of underground mining.

The scientific research department of technological problems of underground mining of deposits is a leading science collective of mining profile in the system of the uranium mining subsector of Minatomenergoprom. The department is made up of seven laboratories (one is an interagency laboratory) and an experimental base, and in addition, research and development of mining equipment is being done by laboratories of three affiliates located directly in mining regions. Work is being done under the supervision of five doctors of technical sciences and 38 candidates. The main staff of scientists of the department was formed back in the sixties at a time of burgeoning assimilation of new uranium deposits in our nation.



Priority areas of research of the department: geomechanical substantiation of safety parameters and improvement of conventional technologies of the most effective systems of development of underground mining of ores under a variety of mining-geological conditions of uranium deposits; development of unconventional technologies of underground and heap leaching of uranium, gold, copper and other metals; creating and introducing low-waste resource-saving ecologically clean technologies in mines; development of technologies, methods and means of protecting the environment against pollution by natural radionuclides when developing mineral deposits, including in mines of the USSR Ministry of Metallurgy and in shafts of the USSR Ministry of the Coal Industry; creating new mining machines and equipment for large-scale mechanization of production processes; air-conditioning mines; developing technologies for effective use of man-made underground spaces for construction of subterranean nuclear electric power plants, pumped-storage hydroelectric power plants, and radioactive waste burial facilities.

We have the experience and up-to-date equipment for determining a variety of physical and physicotechnical properties of rocks and minerals over a wide range of variation of initial parameters (from loose soil to solid hard rock) in strict accord with existing GOST and industrial standards by reliable techniques with observance of control procedures.

The kinetic theory of the strength of solids as applied to rock and processes of destruction of rock is becoming increasingly popular. Thermokinetic parameters are used to calculate processes of destruction of edge zones of underground structures, mine openings, in the technology of using non-explosive means of demolition, destruction of rock under conditions of the action of high alternating temperatures, and so on.

The new and effective method of boundary elements is being used to calculate the stressed and strained state of rocks in the edge zones of mine openings, underground structures, and so on.

Kinetic concepts of destruction are used in combination with methods of boundary elements to calculate the dynamics of propagation of the front of destruction in brittle rocks, enabling prediction of the state of mine shafts, mine openings and rooms, e.g. when compacted ore is removed.

We have developed and introduced into practice a program for calculating processes of displacements of rock above rooms, cavities, and so on. Experience in mine monitoring when working deposits by the underground method will be useful in planning observations of the state of rock masses in other sectors of the national economy.

We were the first in the nation to substantiate the progressive method of controlling rock pressure by hardenable packing, and to put it to use in uranium mines (1958). And the first book about it, "The Use of Hardenable Packing When Working Uranium Deposits," was published at "Nedra" by our colleagues K. V. Myasnikov and V. V. Rudenko (1964). This method is now in use on a wide scale. GORNYY ZHURNAL, No 12, 1990, published an article by N. F. Ivanov, Yu. M. Tsygalov and M. N. Tsygalova, "Effectiveness of Ascending Development of Deposits" under the conditions of the Gayskiy Mine. Uranium mines have been worked in this way for several years: cascade opening of deposits, working sequence from the bottom up, using hardenable packing with definite pre-established compression properties, completely excluding any collapse zone in an undermined rock layer.

Standard flowcharts have been developed and introduced by scientists of the department in cooperation with planners and industrialists for working intricately structured uranium deposits under the most diverse mining-geological conditions.

Technologies for extraction of crystalline raw material, gemstones and natural stone are of interest: ecologically clean non-explosive technologies that considerably increase the effectiveness of rock destruction and avert the formation of residual strains in the massif.

Thanks to "non-intrusive" technology, an emerald druse massing 7550 g was recently taken from the working face of the Malysheva Mine. A committee of gemologists estimated the true worth of the find. The conclusions of the scientists can be summed up in the words: "unique," "rarity," "national treasure." The druse is one of the world's ten best emeralds.

Experimental flowcharts have been developed in addition to the standard flowcharts. The technologies are competitive, contain "know-how," have been patented, and are supported by technical guidelines, working drawings, and standards of the comprehensive quality system.

The new operationally simple technology of underground and heap leaching, which is much less capital-intensive than conventional technology, can be used for working deposits of rare, nonferrous and valuable metals, giving access to enormous resources of

lean and low-grade ores, and enabling rapid acquisition of reserves situated at great distances from industrially developed centers for a lower capital investment. In underground and heap leaching, only 20–25% of the industrial reserves emerge at the surface, dramatically reducing expenditures on environmental protection. Since it has extremely low permeability, rock mass serves as a reliable shield during infiltration leaching, and prevents migration of solutions into the hydrographic grid. At the same time, the high permeability of the preloosened ore that is being leached is a very favorable factor for rapid and effective neutralization of residual harmful substances after completion of the leaching process. Conversion of working and old mines to the new technology reduces operational losses, and extends the life of mines by many years. Utilization of small mobile reusable extraction facilities makes it possible to use underground and heap leaching to work small individual beds that cannot be commercially worked by conventional technologies.

We have developed scientific and engineering principles of geotechnology that are of importance to all sectors where underground and heap leaching can be used, including mining of nonferrous, rare and noble, metals, and especially gold.

The new technologies are ecologically clean, increase the labor productivity of the miner by a factor of at least two, improve health and safety conditions, and reduce overhead on extraction of pay dirt by a factor of 1.5–1.7. The technologies contain "know-how," and are covered by 27 patents.

Low-waste and no-waste technologies, methods and means that meet today's demands of conservation and ecology have been developed by the collective and introduced with high economic effect.

For example, a resource-saving technology for refilling man-made cavities requires minimum expenditures for preventing dangerous undermining of protected objects on the surface and preserving arable lands of the mining concession. The technology is based on refilling cavities with low-strength hardenable mixtures, and/or isolating the cavities with reliable bridging without filling with any material.

When determining the volumes of refilling of cavities, a check is done on the doming stability of the massif, and the concentration of rock pressure and permissible deformations of the ground surface and protected structures are estimated by the "Mulda" and "Kontur" programs developed in the department for the YeS-1036 computer. This was the technology used at a mine of the Tselinnyy Mining-Chemical Combine to refill about 2 million m<sup>3</sup> of cavities. The economic effect reaches 10 rubles/m<sup>3</sup> of refilled space by reducing cement consumption by a factor of 2.5.

The All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology has 35 years of experience in controlling the radiation hazard

caused by natural radionuclides that are widely prevalent and are the main components in exposure of the population.

Our specialists are doing a whole series of scientific research and planning projects necessary for reducing the radionuclide concentration to admissible levels at mines, in the environment, and in populated areas. We assess the radiation situation at any mine, and issue recommendations on reducing pollution of the mine atmosphere by carrying out projects of partial or complete reconstruction of the air-coursing system or applying special protective measures.

Workers in our department were the first in the nation to develop technical specifications for sets of small self-propelled mining machines with electrohydraulic drive. The design documentation was produced by the industrial design organization of the central scientific research laboratory of automation, and experimental models were made by plants. In 1989, experimental models of the new mining machines were mine-tested: UBSh-11G, BUG-65, BUG-65M, PT-1ESh, PT-2ESh and MVN-1DSh. In 1990, the institute did a feasibility study on construction of a mine equipment machine building plant for series production of the new machines. Three type series of machine packages are to be built.

Opening deep levels and working new deposits involves dealing with high temperatures of the mine atmosphere due to strong heating of rocks and geothermal waters on levels being opened, as well as a high degree of mechanization of the work of shaft sinking and stoping. This puts into sharp relief the problem of methods of conditioning the mine atmosphere that are most acceptable from the technical and economic standpoints.

In cooperation with MGTU [not further identified] imeni Bauman, our department has developed a parametric series of mobile gas-expansion air conditioners RVK-1, VVK, VK-D and KVT-6 that work on compressed air and do not require servicing, expenditure of electric energy or cooling water for operation. In addition to normalizing temperature conditions at airless ends, these air conditioners also normalize the radiation situation by diluting radon-containing mine air with clean atmospheric compressed air from the surface without increasing the cross sectional area of mine openings. The air conditioners are covered by 23 patents. The demand for them is roughly 100 per year in mines of the USSR Ministry of the Coal Industry alone. In 1988, the Interagency Expert Council passed a resolution recommending series production of the air conditioners. In connection with conversion, it would seem feasible to produce the air conditioners at an aircraft plant.

The department is considering the question of using subterranean space for construction of nuclear electric power plants, pumped storage hydroelectric power plants and radioactive waste burial facilities.

Since the underground nuclear electric power plant will eventually be buried (within 40-50 years), nuclear plant design developed under the direction of Doctor of Technical

Sciences, Professor O. L. Kedrovskiy provides for preparation, inactivation and burial of radioactive waste during service, and withdrawing spent modules from the nuclear power plant in a structural module that accommodates the underground nuclear electric power plant itself without any liquid, solid or gaseous radioactive waste ever reaching the surface of the ground. The package of underground plant structures contains the necessary installations and equipment for: minimizing volumes of liquid wastes, evaporating and solidifying them, packing into containers and localizing in special chambers or large-diameter holes; preparing solid wastes (equipment, filters, resins, and so on), pressing, packaging and storing them in separate rooms; holding spent fuel assemblies, and storing fuel assemblies that will not be processed in large-diameter holes. Gases are cleaned similarly to the way that this is done in conventional nuclear electric power plants. The sites of the underground nuclear electric power plant and radioactive waste storage facility are chosen on the basis of fundamental principles of stability of the geological zone (low level of seismicity, vertical shifting of the earth's crust and present tectonic processes for more than  $10^4$  years), stability of the structural module, minimum level of filtration of ground water in geological formations that are inert with respect to radioactive wastes (granite, salt, clay). The depth of location of the underground nuclear electric power plant and burial facility are determined by ecological safety that precludes escape of radionuclides to the surface or into aquifers in extraordinary accidents (gas emissions, explosion of the nuclear power plant, and so on).

To avoid spreading of radionuclides into the surrounding rock, underground nuclear electric power plants and burial facilities for storing high-level and medium-level radioactive wastes are sited in rocks with permeability of no more than  $10^{-4}$  darcy, where there are no zones of tectonic fractures, useful minerals or the like in the block of the mining concession. The selected geological block should accommodate not only the mine openings of the underground nuclear electric power plant, but also an exclusion zone with radius of 200–250 m, and safety pillars between the edges of the exclusion zone and zones of high permeability, including a level of free water exchange. After the service life of the power plant has expired, and the necessary holding time following shutdown has elapsed, cores are partly dismantled and buried in the solid waste room, and the remaining core sections are localized in-situ. On all stages of mine working, underground nuclear electric power plant operation and filling of burial facilities, as well as after dismantling the nuclear facility, provisions are made for continual mine and radiation-technological monitoring to check the possible level of the collective dose of irradiation in accordance with IAEA requirements.

In view of the closure of some mines, consideration is being given to the possibility of using subterranean space for building underground nuclear electric power plants, pumped storage hydroelectric plants, nuclear—pumped storage complexes, and radioactive waste storage facilities. An examination has been made of principles of geological substantiation of selecting sites for these structures with allowance for observance of multiple-barrier construction, techniques have been developed for assessing the initial engineering-geology data for selecting a site for the work, and a predesign workup has been done on

siting of an underground nuclear electric power plant with radioactive waste burial facility in a specific mine with geomechanical substantiation of long-term stability of chambers.



**Yu. A. Prokopovich**, deputy chief, scientific research department of technological problems of underground mining, All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology.

In recent years in connection with conversion of basic production, there have also been a number of changes in the main directions of research.

There has been a dramatic rise in the volume of research on mechanics of rocks, environmental protection, and effective utilization of natural resources. Two sets of problems are acquiring the greatest interest in connection with such changes in the directions of research and development.

The first is the set of current scientific and engineering problems of geomechanics in mines. The methods proposed for their solution are a consequence of fundamental geotechnical changes that typify the development of mining in recent years. This relates primarily to maximum concentration of mining work in individual mining industrial regions, which dictates the necessity and advisability of reexamining several requirements for determining the parameters of safety pillars, the sequence of working ore bodies and beds, refilling mined-out spaces and monitoring zones of displacement, a detailed study of rock pressure in the unmined massif, and then its subsequent transformation as sections are worked.

Increasing the depth of mining determines some fundamentally new requirements for doing rock preparation and room work under conditions of dynamic development of rock pressure, e.g. the creation of spatially oriented support and relief elements of hardenable packing or natural rock in mines with allowance for nonuniform distribution of principal stresses that change appreciably as mining proceeds.

Just as important as problems of geomechanics is the scientific-engineering problem of radiation-ecological safety of miners when working mineral deposits, and a limited fraction of the population of towns and cities. Diligent attention has always been given to questions of ensuring radiation safety. The advances that have been made here are beyond doubt: the actual effective equivalent dose is no more than  $\frac{1}{3}$  of the maximum permissible level. On the other hand, issues of the radiation safety of a limited fraction of the population have always been considered a priori successfully solved. Meanwhile, in this area there are and always have been rather complicated problems, and the collective of the department is doing research and development to solve them.

In 1989, the department was commissioned to do a radiation study of coal mines and pits of the USSR Ministry of the Coal Industry.

To do this work, the institute concluded agreements last year with the "Kuznetskugol" Concern, "Severokuzbassugol" and "Karagandaugol" production associations, and production associations of the Ukraine and the USSR Ministry of the Coal Industry.

**Yu. M. Proshin:** "Is your institute participating in development of the comprehensive 'Geotekhnologiya' Target Program under the auspices of the USSR State Committee for Science and Technology?"

**Yu. A. Prokopovich:** "Our institute has submitted its proposals to the USSR State Committee for Science and Technology (in conjunction with the All-Union Scientific Research Institute of Chemical Technology)."

**V. M. Kirpichenko:** "Is work being done at the institute on producing polyethylene pipes for pipeline transport of packing mixtures in underground mining work?"

**Yu. A. Prokopovich:** "In 1989-1990, our department developed wear-resistant pipes based on 273-79-1 polyethylene and polymer additives (scientific supervisor Candidate of Technical Sciences D. G. Gilmanov) with the capability of self-quenching when burned. The pipes are very convenient for transportation, installation and dismantling thanks to low mass (a 1-meter length of 160 mm pipe weighs 6.7 kg), which reduces labor inputs by a factor of 1.5-1.8 in comparison with metal pipe. The low flammability of these pipes has been certified by the Academy of Fire Safety. The cost of one meter of pipe (experimental lot) is 17.0 rubles.

"Upon request of enterprises, we can place orders for pipe fabrication under condition of fund transfer for the polyethylene."

**D. P. Lobanov,** professor, chairman of department of geotechnology of ores of rare and radioactive metals, Moscow Institute for Geological Exploration.

It is with pleasure that I take this long-awaited opportunity to inform the scientific-engineering community about the truly invaluable production-technological, design-planning and scientific research achievements of enterprises and organizations of the mineral raw material complex of the USSR Ministry of Nuclear Engineering and the Nuclear Power Industry. This is especially valuable and important in the present period of revolutionary eradication of the departmental approach to mineral raw material resources in addressing the conservation and ecological problems of the national economy.



Since 1947, our collective has been taking part in providing the mineral raw material complex of the sector with engineering and scientific personnel, continually feeding its intellectual potential with young specialists. In listening to the speakers at the "round table" today, we once more see how high this potential is, and how pitifully little it is utilized in our nation.

For 20 years now, our department has been training geotechnologist engineers who are developing one of the most promising directions of working deposits of various kinds of raw materials by geotechnological methods.

Borehole and shaft leaching, as well as heap leaching have made a good showing in extraction of uranium, and have now begun to be used to advantage in extraction of gold, silver, copper, zinc, lead, molybdenum, manganese, and the rare earth element group. Our department has developed scientifically sound methods of assessing various deposits that are prospective for underground and heap leaching, and has determined basic initial data and geotechnological parameters for planning of experimental industrial sections and industrial-geotechnological complexes.

Well hydrotechnology is being developed in the arsenal of geotechnology, and is now being successfully assimilated in the extraction of high-grade iron ores, on titanium-zirconium deposits, in phosphorite—glauconite and rare earth—phosphorite zones, vanadium-containing asphalts, and construction sand. This pioneering technology is being increasingly used for taking large process samples when exploring deposits, building underground reservoirs for storage of liquid and gaseous products, and erecting foundations, water barriers, and hydraulic engineering structures.

Training of geotechnologist mining engineers is based on fundamentality of education, high professionalism and adaptability to the demands of life, which are reflected in the skill level of such engineers.

The special nature of personnel interactions between the department and enterprises (including foreign enterprises) is expressed in the fact that training of geotechnologist mining engineers will now be done on a contract basis. Enterprises and organizations pick their candidate who is sent by agreement to the department. Such a candidate is accepted as a student majoring in 09.02.03 ("Working Deposits by Geotechnological Methods") without examinations, if the client agrees to compensate the institute in the amount of 20,000 rubles for tuition. The student is housed in a comfortable dormitory, given instruction on an individual academic plan, and is included in scientific research in the current subject area for the enterprise responsible for his enrollment.

If the need arises at the enterprise for training of a geotechnologist mining engineer from among its own engineering technical personnel, the department gives assistance in solving this problem. The time for such retraining ranges from six months to two years, and is established after talks with the prospective student and mutual agreement of the enterprise and the department.

Working in enterprises and research institutes of the mineral raw material complex is a large detachment of doctors and candidates of technical sciences who are defending dissertations with scientific assistance of professors in the department. And today, via a doctoral program, extramural and correspondence graduate program and system of competition, we are training scientific replacements majoring in 05.15.11 ("Physical Processes of Mining Production") and 05.15.02 ("Underground Working of Mineral Deposits") that cover the entire gamut of geotechnological problems of extracting mineral raw material, including from technogenic deposits. In addition to research on the latest technologies of heap and underground leaching of nonferrous, rare and noble metals, competitors for scientific degrees are working on effective processes for underground dissolution of salts, smelting sulfur and mercury, hydrogenation of coal and asphalt, utilizing geothermal heat, and well hydrotechnology. The biochemistry and physical chemistry of geotechnological processes, ecologically clean mineral processing technologies, and deep cleaning of water are finding resolution in the scientific papers of competitors.

The mining component of the mineral raw material complex, self-proclaimed geotechnology, must assuredly play a revolutionary role in the irreversibly growing necessity of assumption of a new technological aspect of this complex.

**GORNYY ZHURNAL:** "Dimitriy Petrovich, based on your work experience, would you name three or four real problems that might be solved with consideration of cumulative data on geotechnology?"

**D. P. Lobanov:** "There was a conference in Belgorod in 1990, a panel of the scientific-technical council of the USSR Ministry of Metallurgy that examined the program of research on borehole hydraulic mining of solid minerals. This is one direction. Another is the development of technogenic deposits, recycling spoils that contain an enormous amount of metal, or working extra-balance ores. Recycling them by various methods is a real task. And there is a tremendous amount of such reserves. As far as I can see, there has been no concentration of specialists to address this problem in the Soviet Union. This question is now being considered at the All-Union Scientific Research Institute for Preliminary Study and Design of Industrial Technology, especially with respect to gold. There are many such facilities. Geologists are faced with the task of studying reserves. These technologies must be raised to a position of priority."

**GORNYY ZHURNAL:** "Gentlemen, we would like to hear an evaluation of this kind of "round table" meeting conducted by the editorial staff of GORNYY ZHURNAL."

**V. N. Mosinets:** First of all, I would like to state that the "round table" meeting has reached its main goal, which was



to inform the scientific-technical community and a wide range of specialists about the intricate problems facing us under conditions of conversion. To some extent, we have been playing a sad tune in bringing you these facts. But cheerful notes can be heard as well in the activity of our enterprises. We have chosen the main areas in which we see a basis for further development of the raw material enterprises of our sector.

The second goal is to offer some marketable commodity to the scientific-technical mining community. Such a commodity is the knowledge that we have accumulated in our sector. This knowledge is quite extensive, and we offer it for the advancement of other mining sectors of our national economy. It is the realization of progressive technologies, it is equipment that we are ready to transfer in any form (either on order, or we will build cooperative plants).

The third goal, which is just as vital, is establishment of feedbacks. We must not merely meet, talk, and go our separate ways. It seems to me that feedbacks will be established. To reinforce them, a series of conferences should be held on the particular problems of individual narrow specialists. Among other things, this year we are planning a Third All-Union Symposium on Radiation Hygiene and Occupational Pathology to which interested specialists may be invited. This year we will also hold a Second Industrial Conference on Geomechanics. You may have questions about these problems, and we are ready to take part in their discussion. Also this year, we hold our first industrial conference on dismantling and mothballing mines, and radioactive rehabilitation of territories.

Anyone interested in these problems may call upon us. I thank you all for taking part in the "round table," and I wish you creative success.

**V. I. Filonets**, chief, mining department of First Main Scientific-Technical Administration, USSR Ministry of Nuclear Engineering and the Nuclear Power Industry.



First of all, I would like to thank the organizers of the "round table" for this meeting. The concerned exchange of opinions that we have seen, and the presentations of the participants are an indication that this step has been useful and important.

Important both for the guests, the hosts, the organizers, and especially for the editorial staff of GORNYY ZHURNAL.

Because of the narrow specifics of the raw material that is extracted and processed, our miners, ore concentrators, and technologists have very rarely and to a limited extent published in the open press any information about their projects, successful and not so successful solutions, discoveries in technology, labor organization, and so on.

That was then. Now we are open for meetings, contacts, familiarization with our successes and failures. The specific nature of our work has left its imprint on all forms of activity of our subsector (mining and processing). Denied any opportunity for cash purchases of equipment, materials or tools, we have been forced to rely entirely on Soviet goods, to work on improving quality, and to develop new machines, units and tools, frequently with a number of institutes of other agencies. In solving these problems, we have accordingly developed an infrastructure, research, design and planning institutes, and laboratories.

Along with solution of the general problems typical of all mining sectors, we were objectively faced from the very inception of the subsector with problems that our science and engineering had never before tackled: dealing with radon, creating special labor conditions, especially sanitary-hygienic systems for monitoring the level of radiation contamination of body surfaces, work clothes and equipment, and preventing this contamination.

Today these problems are becoming urgent for many miners in ferrous and nonferrous metallurgy, and in the coal industry. Our experience, what we have learned, will certainly be useful here as well.

The extremely low content of useful components in our ores has necessitated approaches to drastic reduction of dilution on all stages of ore extraction. An excellent facility for these purposes is offered by ore monitoring stations that clearly separate ore, rock, and extra-balance both for ores that have natural radioactivity, and for ores that have only induced activity. This has allowed us to send cars and dump trucks to unload at spoil banks. Beryllium and lithium ores are graded by induced activity. A very powerful automated facility has been developed for on-site assaying of gold content in drilling mud, and on this basis a computer-aided design system (CADS) has been made that is an integral part of the mine's computer-aided process control system for multiple-option calculations of reserves, working out grading plans, and so on.

In mentioning the mine's computer-aided process control system, I might add that for our underground mines we have developed and are operating effective systems that handle more than 150 tasks in computer-aided mode, in particular, computer-aided measurement of hole depth and spatial position, determination of ore intervals in each of the holes with transmission of this information to a computer, where it is processed with output of a blasting chart for each of the blast-hole rings in the form of graphic material and text. Unfortunately, several systems, and particularly the most heavily used geological mine surveying system will be put out of work in the first half of 1992 because of the drastic curtailment of uranium extraction and shutdown of the mine. So anybody who wants to learn about these systems and see them in operation had better hurry.

Particular mention should be made of the extensive introduction of underground and heap leaching of minerals in the subsector.

Advantages of these methods: low capital intensiveness, minimum period of assimilation (from one to two years from the start of construction to output of the finished product; there have been cases where metal is obtained within six months). Considering that the efficiency of these methods is higher than that of conventional methods of extraction, that work can be extensively automated and is safe, they should be used at every opportunity for extracting many nonferrous, rare, valuable and rare-earth materials, including recycling of enrichment tailings, slag, spoil banks, extra-balance ore and ore manifestations in small deposits. This will yield a high profit in a short time from the sale of goods, and "put bread on the table."

This is not a moot point. It should be made clear to all of us that we can work and hence enjoy the corresponding socioeconomic benefits, only under condition that invested money, generally high-interest credit, is paid back quickly.

These problems are more easily solved by uniting our intellectual, design, planning and production capabilities, utilizing the advantages of each of them. That is why we have gathered at this "round table."

It would be very, very useful to continue such meetings, gaining depth in the business-like, constructive part of development of mining production, comprehensive utilization of ores and country rock, and keeping up on the market situation for all kinds of raw materials both in our nation and worldwide. GORNYY ZHURNAL and its editorial staff can and should play a major useful part in this.

Clearly, it would be a good idea to give the journal more information about mining and processing semiprecious and facing stones by recruiting specialists on mining and processing construction materials for future "round tables."

I thank all of you for your active participation in the work of the "round table."

Until we meet again.

## Navoiyskiy Mining-Metallurgical Combine

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press 18 Jun 91) pp 24-25

[Article by N. I. Kucherskiy, director]

[Text] In 1958, based on uranium deposits of Kyzylkum Province, construction of the first mining enterprise was started: Navoiyskiy Mining-Metallurgical Combine.

In 1964, based on a deposit of gold-containing ores, construction was started on an enterprise for mining and producing gold.

Under difficult natural-climatic conditions, four cities were built according to modern architectural plans with modern housing, child care facilities and schools, shops and hospitals, social and cultural facilities, pools, parks and artificial lakes. Pioneer camps were built for the children, preventive clinics and vacation homes for adults, a State farm was established, railways and roads were built, aqueducts, power plants, and highways. Simultaneously with the cities, construction industry bases were established, shafts and opencut mines, hydrometallurgical plants, a sulfuric acid plant, underground leaching plants, repair shops and machine repair plants, and a computing center.



The combine successfully fulfilled State orders, was of great assistance in the agricultural development of nearby regions, constructing roads, sheepyards, and is still working on construction of the new regional center of Tamddy.

Construction of the main facilities of the enterprise in a short period was made possible by the advanced pace with which the machine repair base was put into service. Central shops started operation in 1962, and a machine repair plant was put into service in 1964. The plant produced mainly nonstandard mining equipment, tunnel shields, electric power line supports, and also repaired trucks and mining equipment. When the foundry was

opened; the machine repair shop started reairing and fabricating gear boxes for large wheel and scoop excavators, spare parts for ore crushing mills, sizing screens, and other items. The machine repair shop is provided with the latest equipment, has large turret and gear-cutting machines with diameters up to 8 m, and N/C machine tools.

The collective of the combine is now involved in conversion. Volumes of uranium mining and production have been drastically cut, and as a result there are considerable numbers of workers and engineering-technical personnel looking for employment. Solution of the problem of employment of all members of the combine is at the center of attention of the directorate of the combine and the sector. Issues of accelerated conversion of the production facility based on the developed scientific-technical potential are being examined in cooperation with the directorate of the republic, oblast and ministry. The main directions of conversion have been defined, and the "Program of Accelerated Industrial Acquisition of the Mineral Resources of Central Kyzylkum in Connection With Conversion and Reorientation of Production to Civilian Goods" has been developed.

The Thirteenth Five-Year Plan calls for the combine to dismantle or mothball all underground and opencut mining, and to accelerate the pace of construction of another gold mining and processing facility with introduction of the first phase in 1993.

The conversion program provides for setting up production facilities based on the machine building plant to turn out lathes in volumes of 50, 100 and 500 in 1991, 1992 and 1995 respectively, and to increase production of "Desna" washing machines.

In future, a plant is to be built for producing passenger and medical elevators with annual capacity of 3000 units; the first phase for 1000 units to be introduced in 1994, and the starting facility for 250 units to be completed in 1993.

In the area of developing production of consumer goods, a production facility for turning "Nitron" fiber into high-volume yarn is to be organized in cooperation with the Navoiazot Enterprise and Navoiyskiy Electrochemical Plant; a sheepskin processing facility will be started in 1991; based on the gold extraction plant, jewelry production will be started in 1992.

A burnt brick plant is also to be put into service in 1991 with capacity of 6.5 million bricks per year based on available clay reserves. This will allow construction of brick buildings; current funded shipments of bricks are inadequate.

The plans of the enterprise include expansion and completion of a program on production of building materials, and consideration of the feasibility of mining and processing marble and granite, possibly setting up joint ventures with foreign partners. At existing machine building sites, work will be continued on assimilating the production of nonstandard equipment for the agroindustrial complex.

At this time, tanks with capacity of 50 m<sup>3</sup> can be produced for storing juice, and reservoirs with 50 m<sup>3</sup> capacity for milk storage. Work is being done on expanding the range of vessels for milk processing.

Applied work experience in processing ores of silver, tungsten, rare elements, salts, quartz and building sand has enabled development of a program for future industrial assimilation of deposits of these materials. A research and development cycle is to be done on a salt deposit, with preparation for industrial assimilation to produce alkali, soda and hypochloride.

There is to be an increase in the volume of extraction of quartz and molding sand to meet the raw material needs of enterprises of Uzbekistan and the combine, and plants for production of industrial glass are to be built.

The combine will continue research on studying the importance of iron-manganese ores. Research is to be concentrated on studying the feasibility of using these ores to meet the needs of the combine for pyrolusite and ferromanganese.

Work must be intensified on exploring and assaying gold reserves for underground mining. Reserves under the edge of the pit are to be opened, explored and worked by three shafts 1500 m deep. Sinking of one of these is to start in 1991.

In light of the accelerated development of gold extraction facilities, working of deposits of other minerals, strengthening of the mineral raw material base of the combine, and increased production of consumer goods, the proposed job package should be considered the major line of development of the combine in reorientation and utilization of freed material and labor resources. Carrying out the proposed conversion program will guarantee full employment of combine workers.

**"Southern Polymetallic Combine" Production Association**

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18 Jun 91) pp 25-26

[Article by A. P. Yezhov, director general]



[Text] By the fortieth anniversary of its production activity, which was celebrated in January of 1991, the association had become one of the leading mining enterprises of the USSR Ministry of Nuclear Engineering and the Nuclear Power Industry.

During all these years, the collective of the association has completely explored several deposits of uranium ore of various scales, geological structure and genesis, but generally situated in remote, unpopulated, nearly undeveloped territories with severe climatic conditions.

To get ore extraction started on each of the deposits has necessitated hurried construction of extended roads and railways, power transmission and communication lines, aqueducts, and modern well appointed mining towns with all the necessary ancillary facilities and infrastructure.

The main content of the work of the collective in former years has been continual expansion of production capacities for extraction and processing of ore, improvement of the organization and technology of work based on introducing scientific and engineering advances, enhancing technical-economic indicators.

This focus, dictated by the demands of the time, made it necessary to concentrate the forces and facilities of the collective on main directions of activity to meet State quotas for uranium and concurrent molybdenum production.

Proven reserves in mines were worked at a hectic pace. Some mines with exhaustion of the raw material base were dismantled, and the fixed capital and settlements there were turned over to the national economy for further use. In place of the dismantled mines,

new ones were set up to work deposits by underground and opencut methods, and with the occurrence of explored hydrogenic deposits, by underground leaching as well.

The long-range plan for development of the sector called for a further increase in production output at "Southern Polymetallic Combine" Production Association by a sharp rise in the proportion of underground leaching in the general volume of extracted raw material. This task required the concerted efforts of all structural subdivisions of the association.

On the path to realization of the "plan..." the collective of the association found itself face to face with the resolution on conversion of production. There is no point in talking about planned developments along possible lines of conversion. There simply were none. All investigations to find new directions of production activity had to be hastily made by the enterprise itself.

"Southern Polymetallic Combine" was faced with the necessity of production conversion under stringent conditions of curtailment of the volume of State contracts for its basic output and a preceding changeover to self-recuperation and self-funding by the second model of cost accounting.

We had to stop working the remaining proven reserves by the underground method in the Eastern and Western mines. These mines were in a stage of development on the flanks and deep levels of deposits with deteriorating mining-geological and mining-technological conditions. Expenditures on extracted ore with allowance for disbursements on hydrometallurgical processing considerably exceeded the maximum sector-wide price for marketable finished goods obtained from the raw material.

It was in these mines that it was decided to set up the new production facilities.

In addition to complex technical and economic issues, there was a difficult problem to be solved: maintaining solid teams of skilled miners, engineering-technical personnel and mine employees, involving unemployed workers in creation of the new production facilities and mastery of new trades.

As a result of searches for the most acceptable directions, the association compiled a program of production conversion.

In accordance with this program, the Eastern Mine of the association is doing preparatory work for assimilation of the Chiganak barite deposit and setting up a mining enrichment complex for extraction and processing of 500,000 metric tons of barite ore per year. This deposit, which is located 100 km from the town of Aksuyek, is to be worked by a watch method in opencut mining on upper levels, and by the underground method on lower levels. Preparation for underground working will be done in parallel with working of the pit.

The first phase of the mining complex will extract 100,000 metric tons of barite ore in 1991 that will be used after appropriate processing to make drilling mud weighting material required for well digging in the petroleum and gas industry.

Simultaneously with construction of the first phase, plans are being made for underground mining, an enrichment complex, and also chemical production to get ultrapure barium salts.

A production facility is being organized to make paints and enamels with capital investments of 2.5 million rubles. Goods valued at 1.5 million rubles are to be produced in 1994, and 3 million rubles worth in 1995.

Facilities are being set up on the basis of the machine repair shops of the mine to make equipment for the agroindustrial complex (digesters, and so on).

Work is being done on a project to organize production of FPP filter fabrics , providing for the use of buildings located at the mine, and structures on the site of a retired exploratory mine. This product is needed for producing individual breathing masks.

In the Western Mine on the production area of a dismantled section of underground mine works, an experimental-industrial production facility has been organized for making ShB-1 "Lepestok" respirators. The necessary equipment has been acquired and fabricated, people have been trained, and 4.5 million respirators were produced in 1989, and 8.5 million in 1990. An industrial production facility is being constructed that is designed for production of 100 million respirators in 1995.

Technology has been developed for making ShB-1M "Lepestok" respirators with nonwoven material. Design documentation is being prepared, and experimental models of "Paris" semiautomatic machines for assembling the respirators have been made.

Experimental work has been organized on taking commercial granite blocks from a nearby pink granite deposit and shipping them to stonemasonry plants. 1123 m<sup>3</sup> of high quality commercial blocks were quarried in 1990.

Steps and curbstones are made from the unconditioned blocks. In 1990, 163 m of steps and 448 m of curbs were made. With the acquisition of stonemasonry equipment (1993), the volume of quarrying of commercial blocks is to be increased to 8,000–10,000 m<sup>3</sup>, and the production of granite facing slabs will be brought to 160,000 m<sup>2</sup>.

In the framework of a production facility set up jointly with the "Kirgizelektrosvigatel" Plant, equipment has been installed in unoccupied buildings of the mine for die casting nonferrous metals with output of finished goods in a volume of 700 metric tons in 1991 and 4,000 metric tons in 1995.

In carrying out the conversion program, in addition to the natural problems that are typical when building and finalizing new production facilities, numerous difficulties arise that are due to the absence of any law about conversion, confusion in the minds of officials on various levels caused by the "war of laws and sovereignties," agitated and exaggerated conflicts of interests of state-wide, republic and local agencies of authority and the enterprise, with the result that the very inception and development of production facilities, and the people who are supposed to operate them are pushed aside. This is the only way that one can explain the delay in granting allocation of lands for new production facilities. Progress is impeded by delays in the beginning of design work, and then by enforced excess haste in designing, disarray of the material-technical supply system, the change to direct agreements with suppliers based on unfair exchange in kind; the intricacies and uncertainties involved in looking for money to rebuild, construct and acquire equipment for new production facilities.

## Priugarskiy Mining-Chemical Combine

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press 18 Jun 91) pp 26-28

[Article by S. S. Pokrovskiy, director]



[Text] The main directions of conversion of the combine are determined by the specifics of its production as a mining-chemical facility, by the industrial potential that has been created, including a heat and electric supply station, machine repair plant, central scientific research laboratory and monitoring and measurement instrumentation and equipment, in addition to the main production facility, by a well developed infrastructure, and by a staff of highly skilled scientists, engineers, technicians and workers.

The conversion program is being carried out under conditions where we have no legislation on conversion, and central funding has been cut off for research and capital construction. The enterprise has to find the money for conversion by reducing production expenditures and using bank credit.

Let me summarize the main directions of combine activity in conversion.

### Mining

Acquisition of the "Urtuysk" Coal Mine is the basis of development of the independent energy base of the combine and of the south of the oblast as a whole. As of now, we have already acquired capacities of 1 million metric tons per year, which will be increased to 3.0 million metric tons.

A zeolite quarry based on the Shivyrtuysk zeolite tufa deposit provides up to 100,000 metric tons of zeolites per year. The capacities of the quarry will be increased as the range of customers for the raw material expands.

A zeolite processing plant is now in operation, producing goods for agriculture. Work is being done on producing modified zeolites with prescribed properties that will allow them to be used as filters, catalysts, driers and prolongers.

An enterprise is being set up at a molybdenum deposit for extraction and deep processing of molybdenum raw material. A watch community is already under construction, ore recovery will start in the middle of this year, and will load the concentration mill of Vershino-Shakhtaminskiy Ore Administration. The volume of ore mined will be 400,000 metric tons in 1992. Pyrite concentrate of the Vershino-Shakhtaminskiy Concentration Mill, which contains metal complexes and gold, as well as tungsten intermediate, will be shipped to Priugarskiy Mining-Chemical Combine for hydrometallurgical conversion. Future plans call for setting up a large enterprise at the deposit that will have high economic efficiency when combined with the potential of Priugarskiy Mining-Chemical Combine.

In Mongolia, at a uranium mining enterprise where the Soviet Union has set up a considerable industrial base and infrastructure, a Soviet-Mongolian joint venture is to be formed for mining uranium and complex ores. Some industrialized nation will be a third party in the enterprise.

Considering the specifics of its enterprise, the combine is focusing efforts on studying the mineral raw material base of Zabaykalye. We are especially interested in deposits of gold, rare metals, fluorites, marl, limestone, and technogenic sources.

#### Hydrometallurgical and Chemical Production

*Processing of gold-containing concentrates.* At the present time, "Zabaykalzoloto" Production Association is having trouble selling sulfide and arsenic gold-containing concentrates. The gold mining industry has no ecologically acceptable technology for processing these concentrates. Our sector has a wealth of experience in processing gold-containing ores. Autoclave-sorption technology has been developed for application to "Zabaykalzoloto" Production Association concentrates, checked in industrial tests, and recommended for introduction. The processing production facility is to be located on the site of the hydrometallurgical plant, using the existing infrastructure. The total volume of processing is 500,000 metric tons of concentrates per year, including 100,000 metric tons on the first phase (1995) taken as a basis for the present conversion program.

*Processing of pyrite concentrates and roasting residues of the sulfuric acid plant.* The scheme for processing pyrite concentrates includes sulfuric acid leaching with extraction of nonferrous metals and final treatment to produce cementation copper or blue vitriol, iron oxide pigment and zinc oxide. After final leaching, storage and dehydration of tailings, ion exchange resin will be used for sorption of gold and silver from solutions with final production of ingots. This arrangement will be used to process the pyrite concentrate of the "Novoshirokinskiy" mine and concentrate from ores of the Bugdanskiy

deposit, as well as roasting residues of the sulfuric acid plant. A version with processing of 100,000 metric tons of pyrite concentrates per year has been accepted for production. In this way, nonferrous and precious metals will be utilized, and the detrimental ecological impact will be reduced.

*Molybdenum disulfide.* Technology for producing synthetic molybdenum disulfide—a base for antifriction additives in engine and transmission oils—has been developed at the combine in cooperation with several scientific research organizations. We have now started production of "Edimola"—a grease for heavy mining and enrichment equipment. The technology for producing the grease was transferred to the combine by the All-Union Scientific Research Institute for Oil and Gas Refining and the Production of Synthetic Liquid Fuel. In addition, we are preparing for production of "Friktol" engine oil additives. Other additives based on molybdenum disulfide are under development and will be produced.

Mention should be made of the high quality of molybdenum disulfide produced at the combine. The synthetic method of production guarantees high purity of the product, and the synthesized molybdenum disulfide is pulverized to a high degree of dispersion: less than a micron.

Foreign companies are interested in acquiring molybdenum disulfide produced by the combine.

*Production of copper phthalocyanine.* A feasibility study of phthalocyanine production is being prepared by the Tambov Affiliate of VNIOPPIK [not further identified]. The conversion program provides for realization of the project by stages. The basic technological plan for production of phthalocyanine pigments involves sintering of the initial chemical reagents in electric furnaces, rinsing out excess carbamide with water, recrystallizing in sulfuric acid, and drying. And what is most important for environmental protection is that 10% sulfuric acid is utilized in main production.

### Machine Building

The machine repair plant of the combine is being converted along two main lines: mining machinery, and equipment for the agroindustrial complex.

We have already started production of PD-2E narrow-cut electrohydraulic loaders designed by NIPIGormash [not further identified]. In 1994, production output will reach 50 per year. Estimates by specialists show that the use of only 10 such machines at the combine will save more than 20 million rubles per year by reducing breaking and processing of dead rock. Besides the combine, the PD-2E machine will be supplied by enterprises of Glavalmazzoloto, which is taking part in funding the work on expansion of the machine repair plant. The main difficulties complicating preparations for production of PD-2E machines are associated with providing the necessary materials, units and subassemblies.



As part of the sector-wide conversion program, the machine repair plant is producing 25-m<sup>3</sup> milk tanks and equipment for the meat-processing industry. However, it must be kept in mind that State contracts for agroindustrial goods are weak in material-technical support.

#### Power

Introduction of the seventh turbine unit of the electric heat and power station in 1991 will bring it to a power of 470 MW, which will raise the delivery of electric energy into the Chitaenergo Power System from 150 to 260 MW.

The development of power-generating capacities is being supported by introduction of the "Urtuysk" Coal Mine.

In addition to the aforementioned main directions of conversion of Priugarskiy Mining-Chemical Combine, plans are being made to construct a minicement plant with capacity of 200,000 metric tons per year, increase supply to the national economy of sulfuric acid, including improved acid, limestone, general machine building goods, spare parts for enterprises of the sector, organize production of some spare parts for agricultural equipment being operated in the region, expand the production of consumer goods, and offer services to the public.

A special concern of ours is increasing the yield of agricultural produce on the "Argunskiy" State Farm that is associated with the combine, and assimilation of the capacities of the meat combine that is a joint enterprise of Priugarskiy Mining-Chemical Combine and Agropromsoyuz.

Conversion will require a change in the approach to training personnel. It is suggested that the combine's present personnel training department be converted to a personnel retraining and skill advancement center.

## Eastern Mining-Enrichment Combine

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press 18 Jun 91) p 28

[Article by N. A. Ganza, director]



[Text] In accordance with the Decree of the Soviet Government on conversion of defense sectors of industry, a program of conversion for the period from 1991 through 1995 has been developed at the Eastern Mining-Enrichment Combine. The purpose of this program is to develop new production facilities for civilian goods. In working out the program, allowance has been made for the factor of forthcoming operation of the combine under market

conditions, and improvement of the viability of the combine under the new conditions of doing business. The course to conversion has taken several directions in production. It has also been taken into consideration that with the existing shortfall of funding money, one of the main principles of conversion is maximum utilization of available production capacities, reconstruction and modernization of enterprises for the production of new kinds of goods.

The main directions of conversion at the combine are:

1. Reorientation toward extraction and processing of complex ores at "Novaya" Mine. This year, work will be competed on ore exploration, calculation and confirmation of reserves at the USSR State Commission on Reserves, and development of technology for ore processing at the hydrometallurgical plant. Provisions have been made for processing

the necessary amount of complex ore this year at an experimental facility to select the optimum processing option.

2. Production of high-quality manganese concentrate at the hydrometallurgical plant from carbonate ores of the Nikopolskiy ore fields. An experimental facility is being assimilated to produce manganese oxide for the electronics industry.

3. Production of electric motors for household appliances (output about 1 million items).

The plan has now been completed, plant construction has been started, 730,000 rubles worth of capital construction had been assimilated on 1 January 1991, and the first batch of electric motors is to be produced by the end of 1991. With this plant as a base, possibilities are opened up for producing a variety of household appliances (food processors, washing machines, and so on).

4. Production of mining and enrichment equipment (electrohydraulic truck-mounted drills, rigs, loading and delivery machines, hydroperforators, shaft elevators, radiometric separators, and other equipment). Based on the central scientific research laboratory of automation and the "Novaya" Mine, plans have been made to build a mining equipment plant to serve mining enterprises of the sector and Glavalmazzoloto. Production volume will total 40 million rubles. A feasibility study of the construction project has now been developed. Construction is to be started in the second half of 1991.

5. Assimilation of technology for producing equipment and facilities for the industrial complex. Based on the machine repair plant with participation of other enterprises of the combine, we can reliably produce grain triers, milk tanks, screw pumps for the dairy industry, facilities for mechanizing beef dressing. The volume of goods produced in 1991 will be about 5 million rubles.

6. Acceleration of the pace of growth of production of consumer goods and public services. For example, the volume of consumer goods produced in 1989 was 1.3 million rubles, and in 1990 it was increased by a factor of 3.1, amounting to 4.1 million rubles. As a whole, with allowance for foodstuffs and services, the volume of production increased to 14.5 million rubles. The pace of growth of output will increase each year on production sections of consumer goods, sewn goods, the machine repair plant of Ingulsk Ore Administration, the central scientific research laboratory of automation, state farms and subsidiary plots.

The approved program of conversion is continuously enriched by the discovery of new reserves, prospective production facilities and directions. Work is in progress on organizing production of granite slab based on section No 2 of the "Bratskoye" deposit in cooperation with a U.S. company.

Questions of organizing some other production facilities are being discussed: glass container production based at Ingulsk Ore Administration (volume of 15 million units), brick at Smolino Ore Administration, and medical grade sorbents at Zheltyye Vody Production Facility. Other prospects are also being considered.

All of this together means that in spite of numerous problems with funding and material-technical supply, the combine is diligently carrying out the first phase of production conversion.

1986 - 1987 years were marked by significant changes in the structure of the combine. The main factor was the transfer of the combine's activities from the Tselinnyy district to the Karatau district. This was followed by the formation of the Tselinnyy Mining-Chemical Combine, which includes the Tselinnyy Mining-Chemical Combine, the Tselinnyy Metallurgical Plant, the Tselinnyy Chemical Plant, the Tselinnyy Machine Repair Plant, the Tselinnyy Heat and Electric Power Station, the Tselinnyy Central Material-Technical Supply Base, the Tselinnyy Central Bases and Production Enterprises of Worker Supply Administration, and other services.

The combine's activities are concentrated on the development and processing of nonferrous metals, gold, industrial diamonds and natural stone of deposits located within the working radius of the combine. These deposits have been worked by special enterprises, and a conversion plan has been developed that has been approved by the Ministry and by the Government of Kazakhstan.

## Tselinnyy Mining-Chemical Combine

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press 18 Jun 91) p 29

[Article by L. P. Luchina, director]

[Text] The Tselinnyy "Order of Lenin" Mining-Chemical Combine of the USSR Ministry of Nuclear Engineering and the Nuclear Power Industry is located in the virgin lands of Kazakhstan. The combine incorporates four ore administrations, hydrometallurgical, chemical and machine repair plants, a mining equipment plant, a heat and electric power station, a central material-technical supply base, central bases and production enterprises of worker supply administration, and other services. Industrial institutes and the central scientific research laboratory of combine have come up with a number of developments that are being directly utilized in production. Among them are: a combined method of working deposits by a combination of underground and opencast mining; a system for sublevel gobbing with flexible floors, the use of self-propelled equipment, group preparation of blocks over the entire length of the ore bed; the use of ball mills, vibrotransport, and electrochemical treatment of mine water in packing work; technology for heap leaching of uranium from extra-balance and low-grade ores, including under winter conditions; underground leaching technology; production and use of hydraulic perforators of the GP series, hydraulic hammers, and so on.



A reduction in the market demand for goods of our sector has led to curtailment of State contracts, which has dictated the changeover of the combine to extraction and processing of ores of nonferrous metals, gold, industrial diamonds and natural stone of deposits located within the working radius of the combine. These deposits have been worked by special enterprises, and a conversion plan has been developed that has been approved by the Ministry and by the Government of Kazakhstan.

One of the main directions of conversion is the "Gold of Kazakhstan" program. In accordance with this project, within the framework of the "Kazmetall" Association to which our combine belongs, plans have been made to use idle facilities of the hydrometallurgical plant for processing pyrite roasting residues of sulfuric acid production, arsenic-pyrite and pyrite ores, concentrates, extra-balance ores and tailings of the gold extraction mills of Kazakhstan, with output of crude gold. Work is being done on the use of cyanide-free underground leaching technology on specified gold ore deposits. A joint enterprise with "Dhezkazgantsvetmet" Production Association has been formed to produce cathode copper from extra-balance oxidized copper ores based on the heap leaching technology that has been set up in our combine.

Primary tasks include assimilation of new deposits of tin (Sarymbet) and industrial diamonds (Kumdykol). The Sarymbet tin deposit is already being explored; on the exploration stage, the combine is organizing an exploratory service production facility, and doing research on determining the process arrangements for processing tin-containing ores. The enterprise has put the Kumdykol industrial diamond deposit on its balance sheet. Work has started on construction of an experimental-industrial complex for processing diamond-containing ores. Research is being done on sintering compacts and using them as a basis for producing diamond tools. We are getting orders from diamond tool customers in various regions of the nation who are ready to deal with us.

As many as ten manifestations of natural stone have been discovered within the radius of operation of the combine. Exploratory work is being completed on three deposits where quarrying of stone blocks and rubble is planned, as well as production of facing slabs. It is proposed that this direction be developed in combination with utilization of industrial diamonds of the Kumdykol deposit in tools for quarrying and working the natural stone.

The "Machine Building" program provides for producing hydroperforators, diesel loading and transport machines, equipment for the agroindustrial complex, and items for the electronics industry. The problem of long-range cooperation with Glavalmazzoloto enterprises has now been practically solved. The combine has agreed to produce PD-3A diesel loading-transport machines designed by NIPIgorskash [not further identified], and to satisfy the demand of client enterprises for these machine during this five-year plan. We are ready to develop production of series GP hydraulic perforators and hydraulic hammers to the volumes of Soviet demand. I believe that mining enterprises and mine machinery plants will be interested in our proposal.

The "Consumer Goods" program calls for bringing the production volume of consumer goods up to the 17.1 million ruble level by 1995. This includes industrial and household goods, household chemicals, building materials, and athletic goods.

Assimilation of conversion capacities will provide employment for all combine workers who have been laid off in connection with curtailment of State contracts for goods of the sector.

Despite the planned forms of cooperation with interested enterprises and available in-house funds, the combine is not sufficiently funded to develop all directions of conversion, which threatens implementation. The question of land allocation for working new deposits, which has not yet been decided, is slowing the pace of work. There has been a delay in passage of a law about conversion of the defense ministry that would protect the interests of enterprise employees, as well as the enterprises themselves in the period of reorientation to the production of new kinds of goods.

## Conversion of the Raw Material Base of Nuclear Engineering and the Nuclear Power Industry

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press 18 Jun 91) pp 30-33

[Article by V. N. Mosinets, professor, doctor of technical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

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[Text] International experience in the conversion of defense industries following World War II unequivocally shows that regardless of socioeconomic conditions, the most effective conversion is accomplished only when it proceeds in directions technologically similar to the basic pre-conversion industry. All attempts to carry out conversion in directions far from the main course entail a drastic increase of investments, and elevation of expenditures for retraining personnel and creating infrastructures.

The main guiding idea of conversion of the raw material base of the nuclear power industry and nuclear engineering should be taken as compensating for the gross output of goods that have become a casualty of curtailment or cessation of mining of certain minerals by organizing mining and production of new goods that are in short supply in our nation, and with economic efficiency that is on a par with the attained raw material base of the sector prior to conversion. The necessity of just such an approach is dictated precisely by the fact that in spite of a comparatively high output volume, in the USSR today the specific consumption of nonferrous, rare and noble metals used in nuclear engineering, missiles and aerospace equipment, electronics and chemistry, metallurgy and machine building, biology and medicine, which define the scientific and engineering progress of society per unit of gross national product, is considerably lower than in such industrially developed nations as the United States, Japan and West Germany, which as a rule do not have their own raw material sources of such metals that completely satisfy the demands of their production facilities. In this context, the specific production of these metals per capita in the USSR is  $\frac{1}{2}$ - $\frac{2}{3}$  the level in industrially advanced nations, and the yearly rate of increase in production and consumption of such acutely scarce materials as

vanadium, tungsten, gadolinium, germanium, europium, gold, yttrium, lithium, molybdenum, niobium, tin, rhenium, samarium, silver, scandium, antimony, tantalum and zirconium is  $\frac{1}{2}$ – $\frac{2}{3}$  the level in industrially developed nations, which inevitably condemns our national economy to a lag in production and consumption of fundamentally new materials and the development of new industries. The high productivity of social labor with respect to final output that had been attained in the sector prior to conversion (40,000–45,000 rubles per person per year) could not be compensated under conditions of transferring workers to the field of construction, production of consumer goods, machine building goods, and building materials, where the productivity of social labor is lower (12,000–15,000 rubles per person per year).

Based on the adduced ruling idea of conversion, its main intentions included:

1. Maximum utilization of the production, scientific-technical and intellectual potential already developed in the sector for expanding production of goods in short supply or developing new production facilities. When creating a raw material base in new industrially undeveloped regions, more than  $\frac{2}{3}$  of the capital investments destined for this purpose are expended on creating an infrastructure, training personnel, building social, cultural and domestic facilities, i.e. areas that do not have a direct production return. In connection with this, the use of the potential already developed for these purposes, retention of the production collective of miners and technologists with their traditionally high level of industrial and technological discipline is a major goal of conversion whose successful attainment enables rapid expansion of the volumes of production of new goods that are in short supply with lower specific capital investments.

2. The creation of fundamentally new technologies and expansion of the area of application of already known progressive high-tech methods of extracting and processing mineral raw material that had until recently been used only in defense sectors, with utilization in other mining and processing sectors of the national economy for purposes of improving the overall performance of raw material sectors. Trenchless opening of deposits and working them with spoil bank causeways, continuous-flow and cyclic-flow technologies of opencast

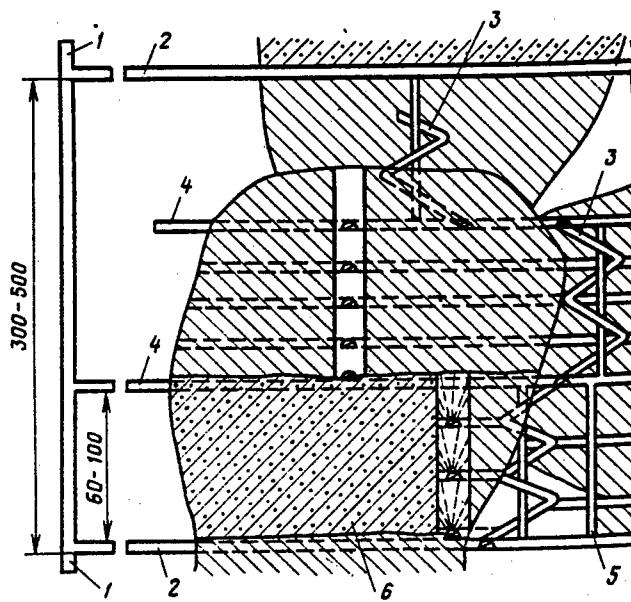


Fig. 1. Scheme for opening deposit by cascades of tiers from the top down, with working of tiers in a cascade from the bottom up: 1—main shaft; 2—concentration level for tiers in a cascade; 3—ramps; 4—intermediate levels; 5—drawhole; 6—hardenable packing

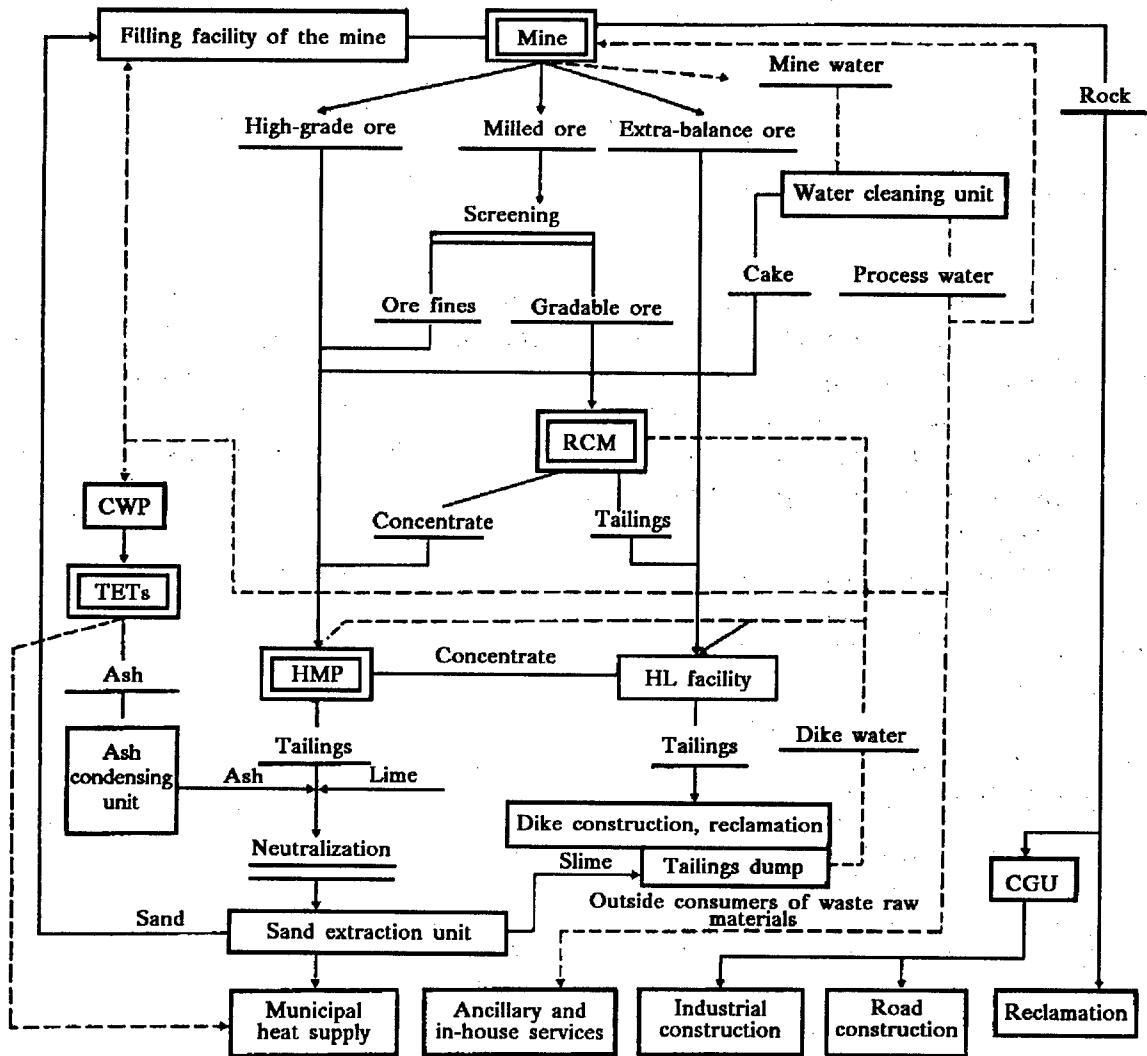


Fig. 2. Schematic flowchart of no-waste (low-waste) working of underground mine: RCM—Radiometric concentration mill; HMP—hydrometallurgical plant; CWP—chemical treatment facility for removing salt from mine water; CGU—crushing and grading unit; HL—heap leaching

mines, multiple-cascade opening of underground mines from the top down with the use of ramps, and working deposits from the bottom up by systems with cementless or low-cement hardenable packing (Fig. 1), underground and block ore leaching, crushing ore without ball mills, autoclave leaching, sorption technologies and many other techniques may be very effectively used as well for extracting gold, vanadium, molybdenum, rare earths, and so on.

3. Creating fundamentally new ecologically clean no-waste production facilities and expanding the range of application of existing facilities for integrated utilization of all

extracted raw material with implementation of three crucial scientific-engineering principles:

appreciable reduction of wastes in processes of opening, preparing and working pits, shafts and mines based on using the latest advances in scientific and engineering progress with group preparation of blocks, reduction of ore losses and dilution, block leaching;

utilization of wastes in related and concomitant mine production processes, in industrial and civil construction, integrated treatment of wastes to obtain new commercial goods with organization of no-waste or low-waste extraction technology (Fig. 2);

isolation of the remainder of wastes from the environment by mine-engineering, agrobiological or structural reclamation of technogenic formations, restoration of disturbed lands and territories.

Based on the above formulated guiding idea of conversion and the most important intentions of its realization, the following projected principles were suggested for carrying them out:

1. Expansion of volumes of extraction on existing mineral deposits, and bringing new deposits under development mainly to compensate for the shortages of acutely scarce kinds of raw and finished materials that are now being imported into the USSR and obtained in limited volume when producing other forms of raw material, or that have a limited market of demand for now and in the future. Although our nation has nearly all kinds of minerals, and is a world leader in reserves of most of them, we annually import millions of rubles worth of mineral raw material while simultaneously exporting it. International division of labor is natural and understandable in today's world economy. No industrial nation has the audacity to produce all industrial goods at home: some fraction is always acquired on the world market. In this connection, considering the possibility of introducing new highly effective deposits in the near future, it is the author's opinion that Soviet import operations should clearly be re-examined with respect to purchases of minerals.

2. Setting up new plants for producing goods in acutely short supply in territories that are in the immediate vicinity of modern mining enterprises under conversion for purposes of most complete utilization of their industrial infrastructure, labor resources and intellectual potential with output of highly effective goods of market novelty with minimum specific capital investments per ruble of salable goods, maximum profit, high level of capital efficiency, and short time of payback of capital investments. Most effective for these purposes, along with development of a sector-wide conversion program, is the creation of comprehensive regional programs that subsume all aspects of conversion of specific enterprises on the given territory.

For example, one such comprehensive regional program (designated "Kazakhstan") on conversion of uranium mining enterprises calls for appreciably increasing the production of marketable goods by raising the output of refined gold, facing stone and building materials, rare earth oxides and alloyage, machine building goods, including mining machinery, and consumer goods, such new materials as chemically pure barium salts, vanadium, tin, industrial diamonds and much more. Programs of this kind are being developed for conditions of conversion of uranium extraction enterprises in other territories as well with effectiveness that will also be high with respect to a wide range of acutely scarce goods that will be produced.

3. Creation of a "quick-response raw material base" that will be supported by new deposits of natural raw materials that are in short supply and other production facilities put into service during conversion, and that will be capable of reacting fairly rapidly under conditions of market relations to demands for new metals and materials that arise in processes of development of progress in science and engineering for solving problems of superconductivity, nuclear fusion, aerospace engineering, a new level of machine building, electronics, household appliances, industrial and civil construction.

For example, even today with a considerable reduction in the interests of the market in extraction of uranium and scandium, tantalum and beryllium, there is a rather appreciable interest in such elements as gold and lithium, rare earth elements and natural facing stone, vanadium and tungsten, molybdenum and tin, rhenium and fluorites, samarium and yttrium, phosphorites and copper. The use of progressive technologies of underground and heap leaching, borehole hydraulic mining and working of deposits from the bottom up from the final depths chiefly by systems with packing and manless extraction, and the creation of small enterprises all dramatically improves the rate of acquisition of new

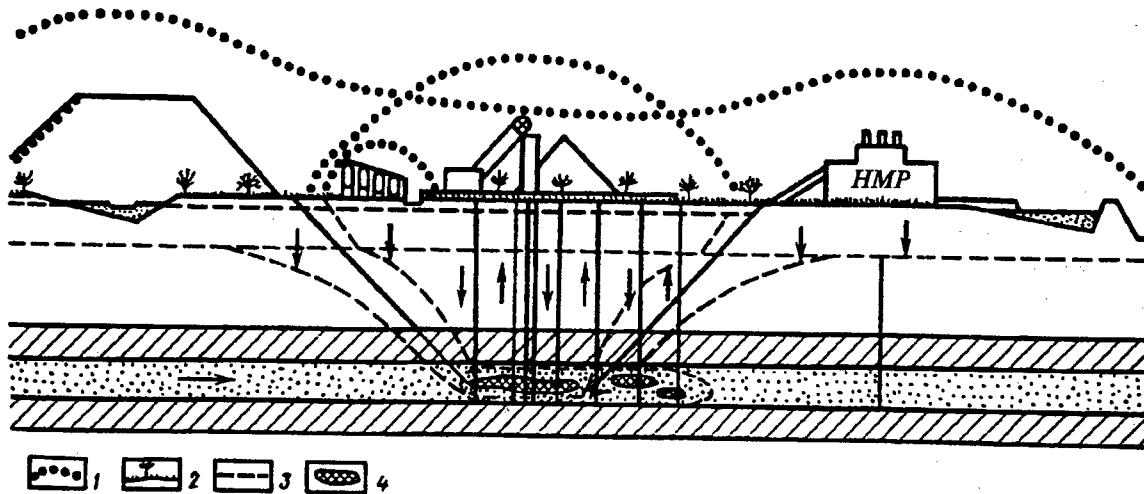


Fig. 3. Characteristic change of halos of contamination of the air (1), ground and landscape (2), underground and surface water (3) and active ore reserves (4) when mining by underground leaching

deposits with creation of the "quick-response raw material base" that will inevitably operate under market conditions. In addition, the introduction of progressive underground leaching technologies considerably improves the ecological situation in regions of extraction of raw materials (Fig. 3).

4. A multiple-option approach to planning of structures of enterprises being converted, providing for different sets of the elements that comprise them both with respect to raw material facilities and with respect to other facilities for production of machinery, low-tonnage chemical goods, consumer goods, building materials and other commodities of "market novelty" necessary for filling the "commodity niches" that arise under market conditions.

Successful realization of this constructive principle is most probable under condition of utilizing all known advantages of today's information community that typifies developed nations: a large-scale data bank on any demand for metals, items made from them or other commodities, computerization of production management with output to this data bank from any personal computer, creation of modern communication facilities, large-scale realization of new technologies and services through stock markets, marketing management of production oriented toward output of what is selling, rather than toward selling what is produced. Only under these conditions can we count on the commercial success of development of new mine facilities, increased production and consumption of nonferrous, rare and noble metals under conditions of conversion to the level of industrially developed nations. In this context, the author believes that as a crucial condition of such conversion, it would be desirable to develop a draft law on conversion in which a major component must be social protection of workers, and preferential conditions for credit investments in setting up new production facilities and reconstructing old ones. Otherwise, the entire conversion concept considered above is doomed to failure, since under conditions of credit at a rate of 15-16% per year, no deposit of acutely scarce goods can be assimilated with any economic effectiveness. If conditions for extending credit to raw material sectors with their comparatively long life cycle of assimilation of deposits are going to be determined the same as for sectors of machine building, light industry and food, in 10-15 years we will have to import all the elements of the periodic table, if we have anything to buy them with. Therefore, questions of preferential credit for investments of raw material sectors and preferential taxation must be among the major issues of protecting the life activity of enterprises of the mineral and power sectors of the Soviet national economy, which should find reflection in the pages of GORNYY ZHURNAL.

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## **Regional Assessment of Mineral Raw Material Base of Sector**

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18 Jun 91) pp 33-37**

[Article by V. G. Ivanov, doctor of technical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

**UDC 553.04.003.13:338.51.001.57**

[Text] No unified procedural approach has been developed as yet in economic science that would enable comprehensive evaluation of the effectiveness of territorial (regional) development of mining facilities.

To assess the mineral raw material base of the region, an integrated systems technical-economic approach has been developed that consists in maximum vertical coverage of the chain of principal connections (raw material—extraction—enrichment—metallurgy—consumers) with allowance for subsector (horizontal) connections.

The following principles have been formulated for geological-economic assessment of uranium mining provinces, which are applicable in equal measure to other minerals as well:

integrated siting of multiple-profile industrial facilities, placing them as close as possible to the raw material base and to priority mining facilities with respect to other forms of economic activity in a given industrial-territorial region;

formation of a combined industrial and social infrastructure;

maximum utilization of existing funds and engineering transport lines on the State, republic and sector levels;

creation of no-waste and low-waste production facilities with the most complete utilization of the entire complex of extracted raw material;

doing multiple-option comparative calculations on substantiating conventional and new technologies for extraction, enrichment and processing of ores with production of finished goods in a given region (republic).

Feasibility studies of industrial assimilation of the mineral raw material base of a region cover two basic points: assessment of individual deposits and evaluation of mineral raw material complexes of geological-economic regions.

Industrial assessment of reserves is understood to mean a multicomponent systems analysis of geological, technical, economic and socioecological interdependent factors. In contrast to the monetary assessment of the deposit, the industrial potential value of the investigated reserves is determined, including both economic evaluation proper, and socioecological consequences of their assimilation, rational utilization of mineral resources, and usefulness of the raw material obtained.

Systems analysis presumes formulation of a hierarchical structure of the goal, and mandatory optimization of the main parameters of stage-by-stage assimilation of raw material resources. In such an approach, the deposit is treated as an element of the system being optimized—the raw material subsector—which in turn is part of the system of the sector, and so on, right up to the highest hierarchical level: the national economy. Clearly, the criterion of assessment of a deposit and optimum parameters for working it, as well as finding the best option for utilizing the assessed reserves, must satisfy attainment of the optimum as a whole throughout the sector. With consideration of the foregoing, Fig. 1 shows a diagram of construction of a model of a systems industrial assessment of uranium deposits that consists of five main blocks defining:

the maximum price (closing expenses) for uranium in mixed oxides  $P_m$ ;

the amount of uranium to be obtained from the given deposit;

depreciation due to losses and damage of natural resources that are detailed by calculations in the work;

possible economic effect due to carrying out natural conservation measures.

The maximum price  $P_m$  is the level of expenditures on obtaining and using mineral raw material that is ultimately attainable from the national economic standpoint. Adjusted expenditures for natural uranium as an alternative energy carrier are determined on the basis of replacing fossil fuel with nuclear fuel when producing electric energy based on optimized long-range plans of development and siting of the fuel-energy complex of the nation, and also with allowance for price changes on the world market. Maximum prices for metal and concentrate are established for individual planning periods. In the case of goods, especially rare-metal goods, for which it is a problem to determine these prices, they can be temporarily replaced by the prices for goods obtained from poor "closure" enterprises whose operation or construction is stipulated in long-range plans.

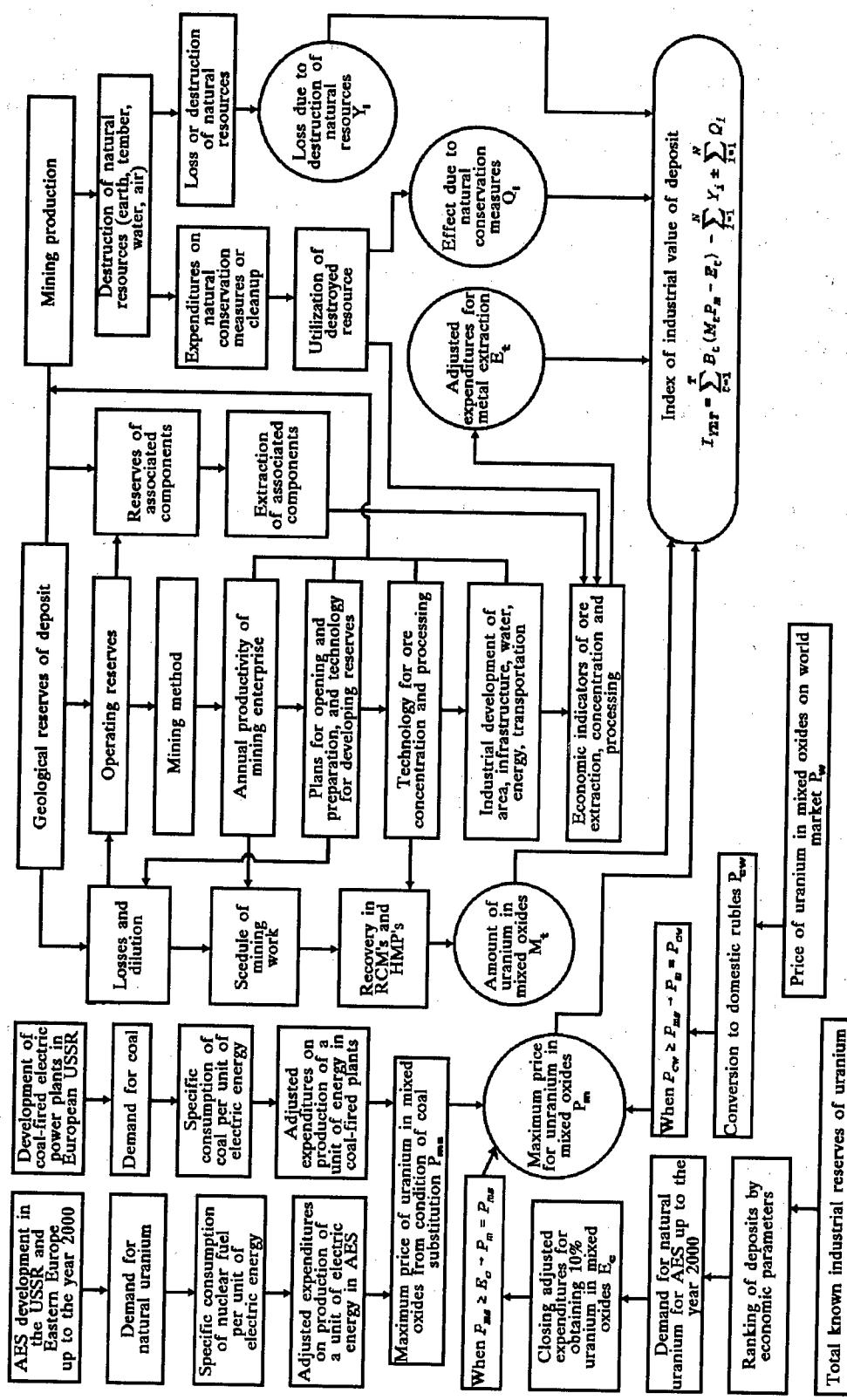


Fig. 1. Model of systems industrial assessment of uranium ore deposit: RCM—radiometric concentration mill; HMP—hydrometallurgical plant

The generalizing index (criterion) of industrial value of a deposit is given by the total discounted provisional profit obtained over the entire service period of a mining enterprise, or the specific profit referenced to one metric ton of liquidated balance reserves. This criterion, analogous in form to the index of differential rent, accounts for all operational expenditures and effective capital investments, as well as the quantity and quality of realized output and its shortfall.

In industrial assessment of a deposit, selecting an effective method of working it, and solving other mining-economy problems, all initial data on options are given in comparable form, except for indicators that are to be optimized. A crucial point when comparing options with time-variable expenses and effects is allowance for the time factor  $B$ , calculated by known formulas. For large deposits, it is advisable to limit the computational period  $T$  to 10–15 years, i.e. to the first phase of operation of the enterprise. Reduction to one time is not done when substantiating the optimum option for contouring balance mineral reserves.

For purposes of technical-economic appraisal of the reserves of a deposit and comprehensive optimization of the parameters of its assimilation, a systems-formalized method has been developed along with a mathematical-economics model and software for computer-aided calculation of principal indicators. The data bank is the revealed mathematical-economics relations and patterns of behavior of the indicators of assimilation of deposits that are being forecast. Computer-aided calculations in interactive mode reduce labor inputs on computational work by a factor of 5.

A systems-cybernetic approach has enabled objective assessment of all explored deposits of the sector, substantiation of differentiated quality requirements for computing reserves, and giving them an economic classification with allowance for different methods of extracting metals, technological properties of ores, arrangements for working them, sufficiency of reserves, and other factors.

To evaluate the raw material base of a sector or mining region, a dynamic linear programming model with integer (boolean) variables has been developed that accounts for all specific factors and resource constraints. The optimized model and software, in addition to enabling a search for the general direction of development of a sector (industrial region), also enable determination of the place and significance of a specific deposit, the method of working it, the annual capacity of plant that is in operation and under construction, priority and times of putting into service, necessity of reconstructing or closing enterprises, optimum distribution of recovered ore with respect to technological arrangements for enrichment and processing, volume of output of byproducts, the most effective siting of concentration mills and processing plants with allowance for the specifics of extractive enterprises, transport links, concentration, cooperation and specialization of production.

The proposed methodology has been used for numerous calculations that substantiate prospective directions of development of the Soviet raw materials base within the scope of a sector-wide comprehensive program of development of nuclear power of our nation, to determine trends and volumes of temporary curtailment of the uranium extracting subsector in view of the slowdown in the pace of construction of new nuclear electric power plants to the point of shutting down or mothballing individual enterprises, and also the change in volumes of geological prospecting.

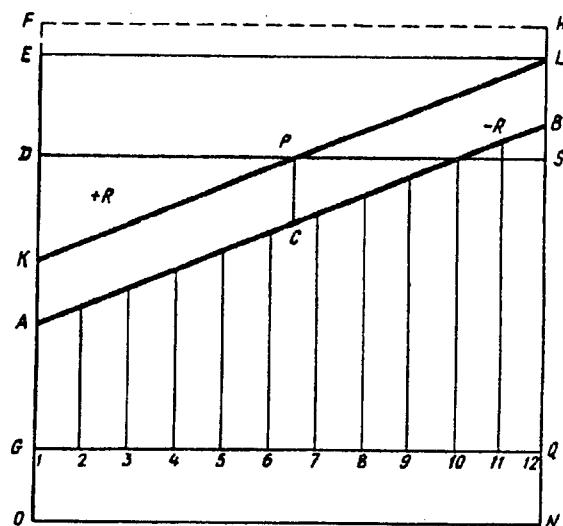


Fig. 2. Diagram of ranking of deposits of the sector: 1-12—number of ranked deposits supporting the planned volume; OGQN—expenditures on geological exploration; GABQ—expenditures on extraction of metal; AK—profit quota; AKLB—profit of the enterprise from sale of commercial goods; KDP—above-quota profit; PLS—subsidies, i.e. rent (+) or (-); C, P—sector-wide average production cost and price respectively; KL, EL, EH—levels of calculated prices, limiting adjusted expenditures and limiting price respectively; OFHN, OKLN—national economic (net) effect or differential rent income

conversion of the subsector by reorienting mining and metallurgical enterprises toward development of nearby deposits of nonferrous, rare and noble metals.

In regional evaluation of potential raw material resources, another problem has arisen that will be a key issue under conditions of transition to market relations in economics: determining the rational level and predicting the change of demand of the national economy, Soviet and foreign markets for given types of goods, especially with allowance for the development of scientific-technical progress of society.

As a result of ranking of reserves (Fig. 2), we establish the sector-wide average production cost and estimated price of 1 kg of metal in concentrate, and subsidies for individual enterprises, the level of limiting (closure) expenditures, and also the values of the national economic effect and differential rent income. It is suggested that the latter be used in working out quotas of payment for mineral rights, and evaluating depreciation due to above-quota losses.

Optimization calculations on development of the raw material base of the sector have revealed an economic standard: the limiting price for metal in finished goods, which is extensively used in solving problems of a lower hierarchical level. In addition, deposits are classified by level of profitability of assimilating them, which is an invariable condition of effective management of reserves under conditions of market relations.

The given theoretical principles have served as a procedural basis for substantiating effective directions of carrying out mining and metallurgical enterprises toward development of nearby deposits of nonferrous, rare and noble metals.

To develop forecasts of shifts in the domestic and foreign market and substantiate optimum tactics for entry of subsector enterprises into the Soviet and world market, engineer A. A. Belugin (All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology) has developed a technique and a mathematical economics model that enable organization of the collection, storage and processing of statistical information in a computer-aided data bank (CADB). The latter is a set of statistical data on market conditions for nonferrous, rare and noble metals, and special software for multiple immediate use of information in an interactive mode. Being the information base of the forecasting system, the CADB provides for storage, primary processing and sorting of large volumes of information, and in addition performs functions of a collective-user reference information service. The modular organization of the CADB and its implementation on IBM-compatible personal computers make the package highly portable. Therefore, the entire software package and database on magnetic media may be installed on any computers upon orders received from enterprises or a ministry.

The developed technique and CADB enable comprehensive investigation and prediction of market conditions of production and consumption of metals in the USSR and abroad, establishment of patterns of shifts in world prices for metals and raw materials, and also successful introduction of marketing methods of production management.

As a result of examination of some alternative options for conversion of individual enterprises and industrial economic regions, recommendations have been made on the most effective rates of development of production of nonferrous, rare and noble metals. The most promising directions are seen to be expansion of the production of refined gold, facing slab, rare earth elements, assimilation of new forms of barite, fluorite, vanadium, tungsten, tin, tantalum-niobium and diamond goods that will totally compensate for the loss from the decline of uranium production. Recommended changes in the structure and volumes of production of various kinds of scarce goods are bringing about conditions for a considerable improvement in the economy of enterprises.

The effectiveness of substantiated directions of conversion is sufficiently high not only because of the planned profit from carrying it out, which will pay back all additional capital investments within 1.5-2 years, but also because it will free highly skilled labor resources and mobile industrial funds that will basically be used by trade membership at production facilities to which they are accustomed, thus maximizing the return.

A regional industrial assessment of mineral raw material resources enables a new approach to substantiation of the effectiveness of working individual mineral deposits. Our technical-economic calculations with respect to some regions of Kazakhstan located near operating enterprises of the subsector have shown that with integrated assimilation of raw material resources and maximum utilization of production facilities and housing, the entire infrastructure of the region, and available labor resources, it becomes effective to work reserves with low content of useful component that by traditional local

assessment had been relegated to the category of nonindustrial or ineffective resources, and for this reason have not been developed.

In contrast to local assessments, in regional evaluations of the development of production, a positive effect can be obtained in the development of lean gold deposits. Of considerable interest is the introduction of new technology for extraction of gold by methods of underground and heap leaching on low-reserve and lean-content deposits by using mobile extraction and processing facilities. When working copper deposits by the method of underground borehole leaching with sulfuric acid solutions and processing of the intermediate product in surface facilities with total metal extraction of about 64%, reserves can be effectively worked with copper content of 0.5–1.0% in oxidized ores. When heap leaching technology is used, processing is very effective on extra-balance and commercially poor oxidized copper ores with copper content of 0.91% ("Dzhezkazgan-tsvetmet" Scientific Production Association).

It may be profitable to develop vanadium deposits that contain a low percentage of vanadium pentoxide by using pyrometallurgy and leaching, and also a tin deposit by the underground method with gravity enrichment and melting granular concentrate or fuming sludge concentrate.

The given examples provide eloquent evidence of the advisability of a change from local assessment with respect to individual deposits to regional industrial evaluation of mineral raw material resources with optimization of the development of mining sectors and forecasting the conditions of the Soviet and foreign markets.

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## New Constructive Approaches to Shoring and Rigging Drilled Mine Raises

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18 Jun 91) pp 36-39

[Article by A. V. Burik, mining engineer, and Ye. A. Kotenko, doctor of technical sciences, inventor emeritus of the RSFSR, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

UDC 622.281

[Text] Over the last two decades, along with the conventional drilling and blasting method of making mine raises by KPV complexes, PShchB shields, and all kinds of drivage shelves, the drilling method has been introduced everywhere. In the Soviet Union alone, more than 700 km of raises are being constructed every year. Drilling almost completely eliminates low-productivity, heavy and dangerous manual labor on drivage of raises, reduces oversized cross sections, ensures high stability of shaft walls, and reduces the formation of cracks in the mine rock. Underground raises are driven by the drilling method in nearly all nations through rocks with various strength and stability.

The beginning of introduction of extensive industrial use of the drilling method of driving raises and large-diameter boreholes dates from the sixties when mines were being made in stable solid rock requiring no shoring. At the present time, in connection with expansion of the area of application of this method in driving raises and large-diameter boreholes, questions of reinforcing them are being studied by institutes, scientific and production organizations in our nation and abroad. At the same time, work is being done to find the most acceptable constructive and technological approaches associated with reinforcing and rigging drilled vertical mine raises.

Various technological schemes are known for shoring and reinforcing raises that allow these labor intensive operations to be mechanized. However, the specifics of drilled raises (constricted conditions, stringent safety requirements) make it difficult to develop new hardware and technologies and to upgrade those already existing for wide-scale use. The increasing demand for raises with different cross sections and functional purpose forces us to look for new more advanced, safer and more productive shoring methods and arrangements.

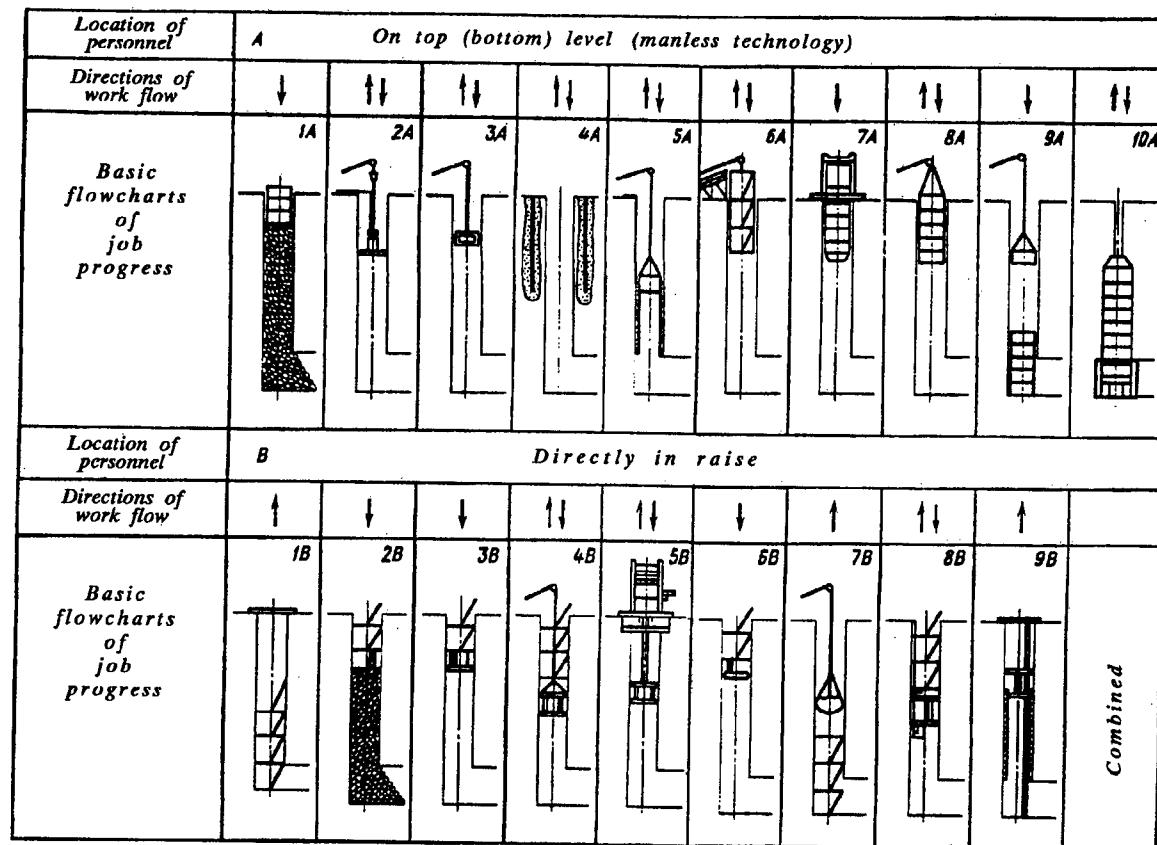


Fig. 1. Systematization of technological arrangements for shoring and rigging drilled raises

#### Hardware and mechanization facilities (see Fig. 1)

Floor	Mechanism					Lowering and hoisting		Drill rig	
	for concrete spraying, guniting, and the like	for fusion	for securing rock mass (grouting, cables, anchors, and the like)	for concrete pouring, putting up forms	power (hydraulic-jack)	winch	hydraulic jack	trailerized rig	
1A	2A	3A	4A	5A	6A	7A	8A	9A	10A
Scaffolding									
—	Floor	suspended and secured			spreader-braced	penthouse	self-powered		
		on upper tier	on upper level	on drill support			Type PV-1000	Type PKT	
1B	2B	3B	4B	5B	6B	7B	8B	9B	10B
Combinations									

The diversity of methods and facilities that have been used up until now, and the lack of generalizing work on technological arrangements for shoring and reinforcing (rigging) raises make it necessary to work out a systematization with allowance for the immediate prospects for development of technological arrangements (Fig. 1 and Table).

A major feature of the proposed systematization is the technology of doing work with allowance for the particulars of hardware. This specific feature allows arrangements to be broken down into two main groups with respect to location of miners: *A*—on the top (bottom) level (manless technology); *B*—directly in the raise. The technology proper for carrying out the work is determined by the hardware and mechanization facilities. Manless technology determines the direction and sequence of job performance.

Rigging of raises in accordance with technological arrangements 2A–5A, 10A and 5B can be combined with drilling, while work by arrangements 4A and 5A can be started even prior to drilling. Arrangement 6A provides for assembling supports and reinforcement while suspended, and in 9A, individual finished components are lowered. A distinguishing feature of arrangements 2B and 1A is prefilling of the raise with rock, water, and the like. Moreover, there is nothing that rules out the possibility of practical utilization of a combined arrangement in which two or more of the given basic technological arrangements are integrated.

The systematization makes allowance both for the current status of technologies for doing work and for possible changes in technological facilities and components.

Work on rigging drilled raises prefilled with rock does not rule out the possibility of wedging. Measures currently used to prevent this are not very effective, and require considerable expenditures of time and money. Moreover, all work is done manually directly in the raise.

The use of suspended scaffolding secured on the upper tier or the upper level, as well as spreader-braced scaffolding, is hazardous, and excludes the use of mechanization facilities, making it necessary to do all operations manually.

From foreign experience, we know of the use of working scaffolding for doing mining operations on erecting shoring and reinforcement mounted on drill rods\* carefully prechecked for strength.

The Soviet pneumatic penthouse (manufactured by Ufa Mechanical Rubber Goods Plant) is used to protect miners and equipment from falling rock. It consists of a shell chamber partitioned into two compartments connected by forward and reverse valves, and a protective jacket. Work is done from the bottom up with delivery of the necessary material by a winch mounted on the lower level. Workers reach the work site by stairs from the bottom up.

Shoring and rigging of drilled raises can be done by using Soviet self-powered scaffolding PV-1000 (auxiliary hoist) made by the Perm Mining Equipment Plant, or

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\* Grosskäner, G. J., Tonscheidt, G. W., "Driving Blind Shafts and Bunkers by Raise Boring Methods," GLÜHKAUF., No 7, 1986, pp 3–10.

PKT-1300 (scaffold for shoring with tubbings) developed by KuzNIUI [not further identified]. The PV-1000 scaffold is a self-powered carriage with transport basket, and the PKT-1300 includes a rope ladder, a moving scaffold with winch and automatic dog for suspending the scaffold on steps of the rope ladder, top and bottom protecting platforms, and a skip for tubbings.

All of the foregoing arrangements and facilities enable performance of work on shoring and rigging of raises when service personnel are located directly at the work site, i.e. in the raise.

Despite the diversity of known hardware and mechanization facilities that allow miners to work outside of the hazardous area, none of them can be especially singled out at the present time. Some of them, like concrete spraying, guniting and fusion (shelling) have not been perfected, and others are glaringly complicated in execution and control (UVT mechanism developed by KuzNIUI: a facility for erecting tubing, simultaneous shoring and drilling), or require extensive work to secure the rock mass.

Unfortunately, extensive use of progressive manless technology for shoring and rigging of mine raises is being delayed by the lack of effective facilities for doing work. At the same time, based on the specifics of rigging raises, a positive result is achieved mainly due to upgrading of constructive features of carrying out the shoring and reinforcement proper. It is the latter that predetermines the rational technical and technological approaches directed at upgrading the process of shoring and rigging. Thus, the constructive implementation of shoring and reinforcement predetermines the technology of job performance.

The All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology has developed and introduced manless technological arrangements for shoring and rigging drilled raises based on new patented constructive approaches.

A stairway (Fig. 2) for reinforcing mine raises 1.8 m in diameter or larger is made in individual sections with central tubular element 2 that is 102 mm in diameter, and stair landing 3, 1700 mm in diameter or larger made of rebar to which ladder 4 is secured (USSR patent No 1334810). Sections are connected by extending element 2, using bolted flanges 5, or welding. The placement of stairs and landings, and the dimensions of manways conform to Universal Safety Rules. It is recommended that No 50-3 expanded metal guard liners be used in slightly cracked stable rocks at points of flaking. There are two options for equipping the passageways of raises: installation of the stairway from the bottom up, or from the top down by using winch 1 for lowering sections. The first option is technologically most feasible, and minimizes the probability of wedging of the structure as it is extended, but requires considerable know-how in organizing the work. The second option ensures high safety of installation work. The total mass of the stairway structure for a 60-meter raise 1.8 m in diameter is 5.2 metric tons.

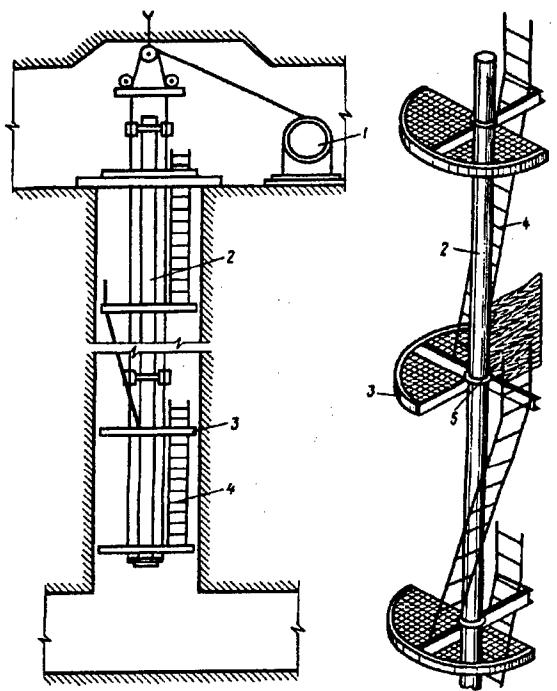


Fig. 2. Construction of stairway with central tubular element

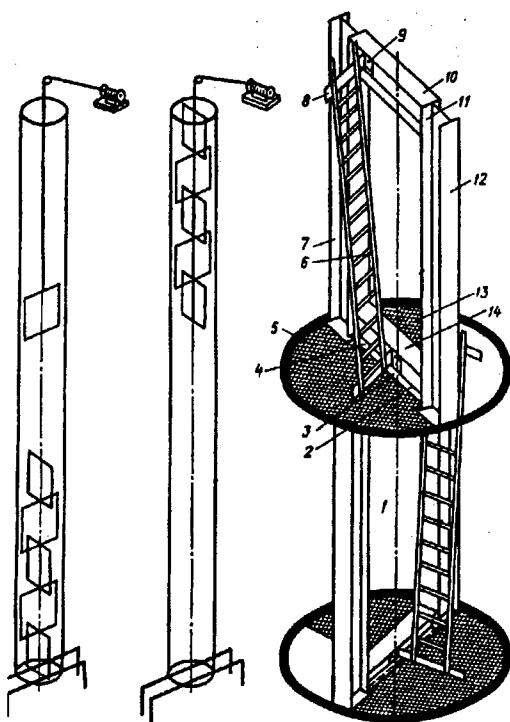


Fig. 3. Stairway in the form of frames for mine raises

A stairway for drilled raises (Fig. 3) considerably simplifies construction, reduces metal inputs and minimizes labor intensiveness for erection (USSR patent No 1287675). It consists of sections 1, each of which is made in the form of a rectangular frame formed by two beams 10 and 14 and two uprights 7 and 12. They are connected by plates 11. The beams and uprights are made of rolled stock (channel, I-beam, angle, and the like). Mounted to beam 14 is a guard platform consisting of two sections: semicircle 5 and sector 13 made of reinforcement formed into a grating. Semicircle 5 and sector 13 are hinged to beam 14 by pipe sections 2 and 4 alternately fastened to the parts being joined, and rod 3 passing through all pipe sections. Ladder 6 is secured at the top to bracket 8 that is connected by hinge 9 to the (upper) beam 10, while at the bottom it passes through the guard platform (semicircle 5) and is clamped. Ladder 6 is mounted between beams 10 and 14 at an angle of no more than 80° in accordance with Universal Safety Rules. The frames are assembled by bolting or welding. When equipping the mine raise, the frames are lowered one at a time by winch from the upper level. The raise can also be rigged from the bottom up with unified construction. In case of the necessity of reinforcing a mine section, a grid is hung around the perimeter of the corresponding stairway (section). The possibility of subsequent anchoring is not ruled out. The sections are transported through the mine assembled and ready to install. In case of necessity, the structure may be disassembled to its component parts. Thus, a stair section is a structure consisting of standardized components, considerably simplifying fabrication, transporta-

tion, installation (assembly) and erection. In the mine raise, No 12 I-beam suffices for construction of the stairway. The stairway can be reused during service.

Based on statistical data about departures from the vertical of boreholes of various diameters and mine raises, it can be stated that a stair lift can be organized when the hole clearance is at least two meters, as safety conditions require observance of a basic requirement: the gap between the pull rope and shoring shall be no less than 300 mm over its entire length. However, based on present-day engineering capabilities, it would be very difficult to meet this requirement for a rise longer than 200–300 m.

With consideration of this situation, a stairway has been designed that consists of a beam hinged to a bunton with the capability of assuming the vertical position (USSR patent No 1067218).

This design permits people to travel through the mine, the borehole with stairway to be used for mine ventilation, and the cross sectional dimensions of the stairway to be reduced.

The design has been implemented in building a safety escape from a ventilation hole with clear diameter of 1.0 m and depth of 280 m. The actual economic effect was 77,300 rubles.

Thus, the use of manless technological arrangements in the mining industry for shoring and rigging raises based on new constructive approaches improves work safety, reduces labor intensiveness of production processes and structural steel inputs, simultaneously increasing the rate of raise rigging and resulting in appreciable savings.

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## Upgrading Technology for Open-Pit Mining of Uranium Deposits

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18 Jun 91) pp 40-42

[Article by A. I. Lukyanov, professor, doctor of technical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

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[Text] Volumes of mining when working deposits of the USSR Ministry of Nuclear Engineering and the Nuclear Power Industry by the open-pit method have been increased mainly by setting up large production associations, using special engineering and technology for mining work, appropriate equipment, large-scale mechanization and automation of all production processes.

Considerable variability of the contents and thickness of ore bodies precludes employment of technological arrangements for mineral extraction that are known to Soviet practice, requiring special research focused on optimizing the work of opening and directional deepening of pits; selection of technology for extraction, equipment and parameters of pits; improving the reliability of operation of process links, attainment of specified indicators of ore losses and dilution; developing ore blending methods; upgrading the technology of drilling and blasting; developing methods and means of normalizing the atmosphere in the pit.

In steeply dropping intricately structured beds, the considerable volumes of overburden stripping during early periods of development tie up equipment and considerably reduce the effectiveness of mining. Mine working conditions are optimized by a set of measures, the principal ones being selection of a method of opening and a system of development, and also finding a rational direction for increasing the depth of pits. For example, in the case of intricately structured deposits that are spread out in the plan view, a transverse-longitudinal system is recommended when opening levels by temporary vehicle trenches, reducing the running coefficients of overburden removal and ore production cost, improving the uniformity of overburden removal by years, reducing the volume of capital

construction work at the mine in the period of pit construction, increasing the rate of working of the deposit, and so on.

Upgrading of the engineering and technology of open-pit work in rock pits of the sector is also achieved by intensifying and concentrating opening and extraction work, including drilling of exploratory service boreholes and blast-holes, blasting, excavation, transport, spoil banking and stockpiling, and reinforcing the edges of pits.

As the depth of worked hydrothermal deposits increases, the hardness of rocks increases by 1-2 Protodyakov categories every 100 m. When the average rate of abatement of mining operations is 10-15 meters per year, practical changes of hardness by 1-2 categories in rocks being worked occur over a period of 8-10 years, which must be compensated by advances in science and engineering in the field of drilling and blasting, necessitating a systematic increase in the specific consumption of explosives.

A specific feature of modern mining operations, in spite of essentially changing conditions of working deep pits, is persistence of the traditionally evolved trends of development of mining and blasting work, i.e. a systematic increase in the diameter of blast-holes, increasing massiveness of blasting, retaining correspondence between the height of the bench being blasted and that of the bench being worked, which in turn corresponds to the scooping height of the excavator. However, for deep pits that are characterized by a continual reduction of the width of work areas, it becomes increasingly difficult to work within these parameters.

This applies especially to questions of blasting preparation of rock. In an effort to improve the quality of blasted rock mass, the diameter of hole charges and volume of explosive charges are increased. Although the quality of breaking at short normalized distances is improved while the quality of breaking as a whole deteriorates, the practice of increasing hole diameter and the mass of explosive charges is continued up to the limiting capabilities of drill rigs, which in turn continue to increase in drilling diameter. However, recent research by V. N. Radionov and V. N. Mosinets [1, 2] has shown that with an increase in the scale of an explosion at the same normalized distances, there is an increase in the average linear size of fragments on the breakage front as a consequence of the increased length of the blast wave and reduction of the rate of loading of rocks.

Considering the necessity of retaining multiple-row short-delay blasting even under conditions of decreasing width of work areas, it is advisable when working deep pits to use hole charges of reduced diameter—up to 150-160 and 190-250 mm (instead of 270-320 mm or more)—with more effective placement in the massif. When small-diameter charges are used, the rate of loading of natural cracked rocks is so high that they are broken in the most optimum energy state, attaining a speed of crack development close to Rayleigh wave velocity.

A second important condition of the development of blasting operations in deep pits is changing of certain concepts and assumptions in the area of parameters of the method of mining. This applies primarily to increasing the height of blasted benches to 25–30 m, and in future even to 50 m. To satisfy safety requirements on correspondence between the height of the blasted bench and the scooping height of the excavator, high blasted benches must be divided into sub-benches with location of equipment on the blasted rock mass. Experience shows that for high benches, the use of blasting technology with preservation of the geological structure of massifs with coefficient of loosening of rock mass of 1.12–1.14 enables highly effective realization of the entire work cycle from sub-benches with location of equipment on the blasted rock. This enables considerable enlargement of work areas and independent management of drilling and loading–transport operations.

Thus, upgrading of the concept of "bench height" with differentiation of "height of bench being blasted" and "height of bench being worked" to a great extent enables reexamination of the technology of mining in deep pits as well, especially in pits where intricately structured deposits are being worked.

Extensive experimental–industrial studies under conditions of open-pit mines of the sector have shown that blasting with retention of the natural geological structure of ore bodies reduces the specific consumption of explosives by 20–25%, the production cost of drilling and blasting work by 15–25%, mineral losses by 30%, and raises the yield of blasted ore mass per meter of hole by 10–12%.

The economic effect from introducing technology for blasting with retention of the structure of the massif in three open-pit mines was 4.1 million rubles per year.

A specific feature of these deposits is the extremely complicated probability characteristic of distribution of ore bodies by content and thickness. Typically, variance of the distribution of thickness predominates over the average, while the average content simultaneously predominates over variance of the content. This probability characteristic is complicated still further in that in its mass, the distribution of ore and oreless inclusions may correspond to the distance between boreholes aimed at finding them, but may also differ from this distance. When working intricately structured deposits, it is most important to determine the geometric parameters and elements of occurrence of structural units, and on this basis select methods and technology for ore extraction.

For these purposes, we can introduce the hierarchical systematization of intricately structured deposits proposed by D. Ya. Surazhskiy [3] that singles out ore bodies on the first and lowest hierarchical level, ore beds on the second level, ore zones on the third, and the ore deposit on the fourth and highest level. Under these conditions, the general trend toward decreasing selectivity in working increasingly leaner deposits by the open-pit method is coordinated to a certain hierarchical level.

Experience shows that passing from the lowest hierarchical level with contouring and selective extraction of ore bodies to a higher level with contouring and extraction of ore beds appreciably simplifies the technological contours of mining and work organization. In this case, the ore bodies that form ore beds are extracted as a whole in bulk, while ore beds in the system of ore zones are extracted selectively; excavation is done along the strike with extraction of ores by grades, or across the strike with face ore blending, which is dictated by the economics of operations.

Raising the hierarchical level of selectivity from ore bodies to ore beds considerably simplifies representation of the structure of deposits, enabling more effective development by using technological approaches that now correspond to the morphology of beds, rather than to the morphology of ore bodies, appreciably extending the possibility of using open-pit mining operations at increased depths thanks to improvement of the economic effectiveness of the work. Choosing a level of selectivity as a function of the hierarchical structure of the deposit essentially predetermines the parameters of mining methods and approaches used for opening deposits.

A specific feature of opening deposits when they are worked at great depths is the use of engineering approaches that essentially reduce the cost of transportation. As the depth of open-pit mining operations increases, there is a significant change in both the production cost of 1 m<sup>3</sup> of stripping, and the structure of mining. In practice, for every 100 m of increase in depth, there is a 40–45% increase in the production cost of stripping, mainly because of the increased cost of transporting rock, which for the same 100 m increases by an average of 70–80%, while the increase in expenditures on drilling and blasting work, excavation, spoil banking, road maintenance and other items is quite minor. For pits being worked at a depth of 50–100 m, the fraction of the production cost per cubic meter of stripping is 25–30% for drilling and blasting operations, 10–12% for excavation, 40–45% for transportation, and 10–15% for spoil disposal. With a further increase in the depth of pits, the cost of transportation reaches 65–75% of the total production cost of stripping. Under these conditions, the proportion of the other items of expenditures considerably decreases, but in exchange, new expense items appear: for ventilation of the pit space and keeping the edges of the pit stable.

The intensive increase in the cost of transportation is due not only to an increase in the distance of travel, which in itself is certainly very important, but also to a change in the conditions of operation of transport. When the depth of pits increases to 150 m as compared with operations on the 0–50 m level, the productivity of BelAZ-548 dump trucks decreases by a factor of 1.5, while that of the BelAZ-540 decreases by a factor of 1.8. This is because of a reduction of average speed by 40% and 25% respectively, and also a 20–25% decrease in the availability factor of dump trucks because of strenuous operating conditions. For this reason, when opening and preparing deep levels of pits in the sector, approaches aimed at reducing the distances of transporting rock are being more and more extensively used.

For example, at one of the open-pit mines of the sector characterized by considerable distances of rock transportation, complicated conditions of occurrence of ore bodies and considerable pit depth, comparative technical-economic studies have been done on combined pit transport operations: rail, truck, truck—rail and truck—skip.

The best option for normalized expenditures in working the deposit is the use of combined truck—conveyer transport: normalized expenditures in this case are 8 million rubles per year less than when using BelAZ-549 trucks alone for transport.

In combined truck—conveyer transport, the overburden, and subsequently the ore as well, is loaded by cyclic-action excavators into dump trucks on the +60 m level and delivered to crushing and loading stations. The stations are located on concentration levels. After transshipment, the rock is transported by belt conveyers with productivity of 4000 m<sup>3</sup>/hr (in loose mass) to an overburden spreader with 80 m boom, and then to spoil banks as much as 100 m high, while the ore goes to stockpiles.

A crucial problem in working deep pits is maintaining productivity of the main mining transport equipment. Thanks to upgrading of mining methods and optimization of their parameters, despite the increasing depth of pits of the sector in recent years, we have managed to reach a rock blasting productivity of 2.7 million m<sup>3</sup>/year for the listed EKG-8I excavator, and as high as 3.3 million m<sup>3</sup>/year for individual teams. The productivity of the EKG-8I excavator was 5 million m<sup>3</sup>/year when working sedimentary deposits. The productivity reached on ERG-400/1000 wheel excavators working on blasted rock was from 2.75 to 3.2 million m<sup>3</sup>/year, and on the ERG-1600/3000 was from 6 to 9 million m<sup>3</sup>. On KGTO-2/1000 wheel excavators working under less severe conditions with unblasted rock, this index reached 5 million m<sup>3</sup>/year, from 650,000 to 811,000 ton-km/year per listed BelAZ-540 dump truck, and as high as 1.2 million ton-km/year for the BelAZ-549. The productivity of SBSH-250MN drill rigs is 50,000–56,000 [unit missing] per year. If we can hold these indices of basic mining equipment, we can count on maintaining comparatively high technical-economic indicators of open-pit mining operations even with increasing depth of pits.

A critical problem when working pits is maintaining the stability of the edges. When they have been built to the limiting position, this is done by making shield trenches. However, at pits where the height of paired benches in the limiting position is 30 m, this method cannot be used because of the lack of high-capacity rigs for making trenches by drilling holes 200 mm in diameter and 50–60 m deep at an angle of 40–50° to the horizontal.

In this connection, series-produced SBSH-250MN rigs are being refitted in open-pit mines of the sector. Results of industrial tests of a rebuilt rig in rocks with Protodyakov hardness factor  $f = 8-10$  are given below.

Axial force, kN	100–200
Speed, $s^{-1}$	1.53–2.1
Rate of air flow, $m^3/s$	0.41
Average drilling rate ( $f = 8–10$ ), m/hr:	
at an angle of $55^\circ$	27.8
at an angle of $40^\circ$	21.5
Drilling productivity, m shift:	
at an angle of $55^\circ$	95–100
at an angle of $40^\circ$	55–75

Further reconstruction of SBSh-250MN rigs has enabled drilling holes to depths of from 40 to 50 m at angles of 43, 55, 65, 70 and  $75^\circ$  with diameters of 190, 215 and 245 mm.

Comparative tests on determining the most effective construction of charges when blasting holes of a shield trench have resulted in recommendation of hose explosives based on PZhV-20 and No 6 ZhV ammonites. The productivity of labor when blasting with these explosives is quadrupled on a 15-meter bench, and quintupled on a 30-meter bench as compared with explosives of "string" and "sleeve" design. The contour of the edge bank is smoother, the hole tracks are more distinct, and residual deformations are minimum. It is recommended that enterprises increase the distance between hole charges in the trench from the 2 m proposed by the plan to 2.5 m. Excavation in the edge zone is done with the EKG-4u excavator with extended working parameters.

Creation of shield zones of this kind also protects deposits where natural stone is being mined. There is a corresponding technology that determines the limiting distance where blasting operations must stop.

Introduction of the latest high-productivity equipment and technological approaches at deposits of the sector has enabled attainment of high technical-economic indicators, but has simultaneously led to the necessity of accelerated realization of a comprehensive ecological program for environmental protection, since open-pit mining operations have become a major source of industrial dust and gas emissions into the atmosphere.

A systematic study of geochemical processes that have an effect on the air in open-pit mines has resulted in a comprehensive program aimed at developing methods and means of normalizing the atmosphere in the pit [4].

Dust and gas emissions from pits into the atmosphere cannot be completely suppressed by means of artificial ventilation alone. In this connection, steps are now being taken to eliminate the ecological contamination of air by technological processes in open-pit mines: introduction of exhaust gas neutralizers for mine dump trucks; updating exhaust gas systems with the use of neutralizers and systems for cleaning gases by passing them through the rock being transported; using diesel trolley cars on stationary sections of the route.

Studies and experimental-industrial work have been done by the All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology in close cooperation with IGTM [not further identified], Ukrainian SSR Academy of Sciences, the department of problems of wildlife management and regional economics of ITM [not further identified], Ukrainian SSR Academy of Sciences, the Mining Institute of the USSR Ministry of Metallurgy, the Mining Institute of the Siberian Department, USSR Academy of Sciences, Moscow Institute of Geological Exploration imeni Sergo Ordzhonikidze, Moscow "Order of the Red Banner of Labor" Construction Engineering Institute imeni V. V. Kuybyshev, the Mining Institute imeni A. A. Skochinskiy and others, and also production enterprises of the sector. Plans are being made to expand research in the area of upgrading processes of open-pit mining operations, creating cyclic-flow technology, effective structures for high-quality ore preparation for the consumer, and integrated assimilation of deposits, no-waste and low-waste technology. One way to achieve the most complete extraction of metal is realized at one mine by using the method of heap leaching from run-of-the-line ores with low metal content and spoils of off-grade raw material, which in turn reduces the volumes of ore extracted from the mine, slows down the pace of increasing depth of the pit, and thereby improves the ecological state of the air and subsurface in the zone of the mining concession.

Moreover, on the working planning stage, consideration is given to options of using resources of reserve stockpiles within the mine, moving loads through shafts on lift conveyers, creating concentration levels with extension conveyer supports and rock chutes for redistributing transport flows as mine operations descend.

Since the problem of dust and gas suppression has not been completely solved, equipment is being introduced in the mine for self-contained and individual protection of miners from the injurious effects of carcinogenic agents by hermetic sealing and retrofitting the cabs of excavators, dump trucks, bulldozers and transshipment stations on the cyclic flow line with regenerating units.

Despite the extensive use of measures to control dust and gas in the atmosphere of deep pits, the problem of ensuring safe working conditions for miners and keeping the mine area ecologically clean remains very crucial, and requires development of a Soviet-wide research program involving all institutes of the given profile with appropriate centralized funding.

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## Experience in Operating Cyclic Flow Processing System at Muruntau Mine

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[Article by L. M. Demich, mining engineer, O. N. Malgin and V. N. Sytenkov, candidates of technical sciences, Navoiyskiy Mining-Metallurgical Combine]

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[Text] According to a plan drawn up by the State Design and Planning Scientific Research Institute of the Coal, Ore, Petroleum and Gas Industries based on research results of IGTM [not further identified], Ukrainian SSR Academy of Sciences, a cyclic flow processing system (CFPS) for the Muruntau gold ore open-pit mine is designed for transporting overburden rock (average yield of 500 mm fraction 1.8-2%), and consists of a cyclic link (EKG-8I and EKG-12.5 excavators, BelAZ-549 and BelAZ-7519 dump trucks) and a flow link (two conveyer lines, including four conveyers with belt width of 2 m and one overburden spreader each). The cyclic and flow links are interfaced by four crushing and transshipment stations located on four concentration levels (every 30 m depthwise of the pit) opened by a steep ( $15^{\circ}$ ) trench of internal emplacement. Operation is in three 8-hour shifts with a continuous work week.

The crushing and transshipment station (CTS) includes a receiving hopper with capacity of 300 m<sup>3</sup>, a 1-24-150 apron feeder of heavy type, and KVKD-1200-200 gyratory crusher. Installation of the first conveyer line was completed in October 1984, CTS-1 in March 1985, CTS-2 in February 1986, and CTS-3 in May 1989; work is being completed on CTS-4. The hiatus between completion of construction of the first conveyer line and CTS-1 was used to test equipment and train service personnel. For this purpose, at the suggestion of mine workers, a grizzly transshipment station was built that is still in use to this day.

The working conditions of the CFPS are characterized by a number of specific features due to the mining engineering characteristics of the pit and the engineering approaches used as a basis for design. Among such features are:

alternation of ore and oreless sections;  
inhomogeneity of physicomechanical properties of the rock mass;  
lag of transshipment stations behind the zone of intensive stripping operations;  
combined operation of the two conveyer lines;  
rigid connection between the cyclic and flow links;  
capability of transshipment stations to work with either operating conveyer line.

Because of the alternation of ore and oreless sections, the grade of the rock mass at the excavator face changes several times during a shift. This in turn necessitates a change in the routing and number of dump trucks, which impacts on the rhythmic supply of rock to the CFPS.

The inhomogeneity of physicomechanical properties of the rock mass is detrimental to the quality of rock fractionation by blasting, and increases the yield of oversize on individual sections. Therefore, about 5% of the rock containing oversize pieces, which would result in inevitable shutdown of the transshipment station, is hauled by dump truck directly to the spoil bank.

Lag of transshipment stations of the CFPS behind the zone of intensive stripping operations because of the slow pace of construction has resulted in an appreciable increase in the distance of rock transportation (1.5 km according to the plan, and 2.2 km actually), and the necessity of driving loaded dump trucks from the upper levels of the pit to the transshipment stations on a grade, which impacts on the reliability of their operation.

Combined operation of the two conveyer lines provides for both simultaneous (36% of the time) and alternating (64% of the time) operation, which is linked to planned and emergency shutdowns. This necessitates constant shifting of the excavator and truck fleets to regulate the intensity of rock flow. For example, two operating conveyer lines take rock from 12 faces, one operating line takes rock from only six faces, and the rest must route their rock to the spoil bank (travel distance of 5.5 km) or be readjusted for mining ore of different grades, which is not always possible.

Rigid connection between the flow and cyclic links can be attributed to the lack of time reserve between them (the capacity of the reception hopper of the transshipment point is 300 m<sup>3</sup>, and it is almost continually filled with rock); therefore, when the flow link fails, unloading of dump trucks at transshipment points stops, as they are routed to the spoil banks, and restoration of the original traffic intensity after correction of the failure takes time (30–40 minutes). This results in no-load operation of the conveyers and reduces the productivity of the CFPS as a whole.

The capability of transshipment stations to work with either operating conveyer line improves the operating reliability of the CTS, since when one conveyer line fails, the transshipment station can be immediately switched to the other line.

Comparison of the planned and actual indicators of operation of the CFPS is given below.

Indicators	Planned	Actually achieved
<b>Operating time per year, hr:</b>		
conveyer line	4,800	4,654
CTS	—	4,315
<b>Annual productivity, thous. m<sup>3</sup></b>		
conveyer line	12,800	7,829
CTS	6,400	13,691
system as a whole	25,600	13,691

The reasons for the considerable divergence are that the plan:

did not account for the reliability indices of the cyclic link of the system, and did not determine the influence of these factors on productivity of the flow link;

did not establish the structure of the time of combined operation of the two conveyer lines; did not allow for the possibility of independent failure of conveyer lines and transshipment stations; did not determine how much of the time they would be operating in full complement, and how much in less than full complement (e.g. with a smaller number of transshipment stations);

did not coordinate the operating conditions of the cyclic and flow links of the CFPS; in particular, the cyclic link operates with a lunch break, and therefore the actual time of conveyers in moving rock is 2.5–3 hours per day less than specified in the plan. Also, no allowance was made for the time to recover the rate of unloading of dump trucks at transshipment points to the minimum level following emergency shutdowns of conveyers. No technical or organizational measures are provided for eliminating the consequences of such losses of time (Fig. 1). The divergence in modes of operation of the cyclic and flow links of the CFPS reduces the time of their combined operation by 15%. The absence of temporary backup (buffer stockpiles) between the cyclic and flow links results in downtime of the cyclic link during emergency outage of the flow line (12.5% of the time) and no-load conveyer operation (5.7% of the time) following correction of the malfunction and during startup. As a whole, these faults result in only 70% utilization of the capabilities of the system;

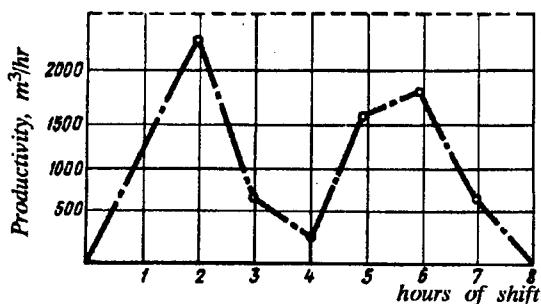


Fig. 1. Dynamics of productivity of transshipment station of cyclic-flow system during a shift

extent of 92%. Operability of both conveyer systems enables attainment of 81 and 57% of the rated productivity of the flow link per shift and per month respectively (Fig. 2).

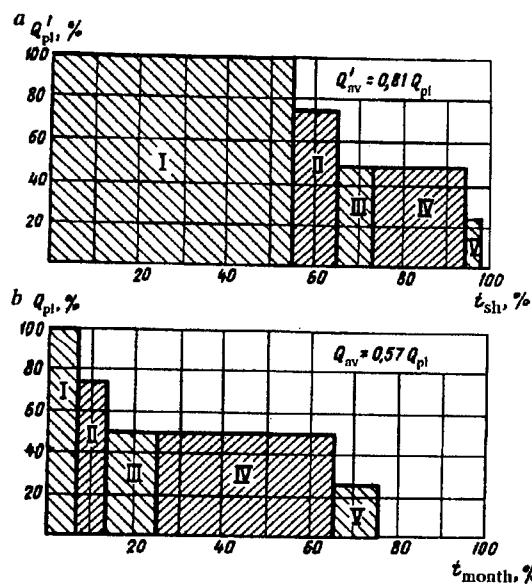


Fig. 2. Change of productivity of flow link during a shift (a) and a month (b):  $Q_p1$ ,  $Q_{av}$ —planned and average productivity of flow link;  $t_{sh}$ ,  $t_{month}$ —time of shift and month; I—2L + 4T; II—2L + 3T; III—2L + 2T; IV—1L + 2T; V—1L + 1T—complement of working link (L—line; T—transshipment station)

practically from the very start of assimilation of deposits at which the use of such systems is planned;

did not confirm in practical mining work the principle of organization and operation of the CFPS providing for using it to transport all rock, since some rock faces cannot be left without disrupting the balance of mining operations.

Calculations done by using probability theory based on the actual reliability indices of facilities of the CFPS have shown that the cyclic link of the system can supply rock to the flow link to the conveyer lines and the four transshipment lines productivity of the flow link per shift and per month respectively (Fig. 2).

Thus, the reliability of operation of the cyclic and flow links of the CFPS and the conditions of their operation preclude complete utilization of the capabilities of the system. To extend these capabilities at the mine, the CFPS is used for separate transportation and stockpiling of rock and extra-balance ore (in 1990, 2.4 million  $m^3$  of ore and 11.3 million  $m^3$  of rock were hauled). Provisions have been made for creating a reserve of equipment and intermediate stockpiles for finishing the loading of conveyers between shifts and during lunch breaks. These measures will enable the system to handle 17–18 million  $m^3$  of ore and rock haulage per year.

Experience in building and operating the CFPS at the Muruntau mine leads to the following conclusions:

mining operations must be done with allowance for construction and operation of cyclic-flow processing systems

at mines with diversified rock mass, cyclic-flow processing systems should be used for transporting and selective stockpiling of rock and ore;

in planning, allowance must be made for the operability and conditions of interaction of cyclic and flow links and evaluation of their impact on productivity of the CFPS as a whole;

the effectiveness of cyclic-flow processing systems can be enhanced by using buffer storage between cyclic and flow links.

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## Economic Effectiveness of Combined Gobbing of Empty Spaces When Working Intricately Structured Deposits

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[Article by Ye. A. Kotenko, doctor of technical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology, and V. I. Golik, doctor of technical sciences, Tselinnyy Mining-Chemical Combine]

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[Text] When working mineral deposits by the underground method, the mined space may be packed, collapsed, or isolated without filling with material. The gobbing method determines the economic, ecological and social consequences of mine working, and therefore the problem of gobbing empty spaces without disturbing the surface of the ground by using economically acceptable and reliable methods is a crucial issue in development of deposits.

According to the accepted method of calculating economically feasible options for gobbing empty spaces, no assessment is made of the actual loss due to destruction of the earth's surface, and losses of raw material due to collapse of massifs. With respect to normalized expenditures per m<sup>3</sup> of gobbed spaces, methods with collapsing of rocks are more preferable, which explains their wide prevalence. The result is irretrievable damage to the environment, including in areas of high population density with intensive utilization of land.

Until the development of scientifically sound methods of evaluating damage to the environment, it would be advisable to discontinue the method of gobbing cavities as a means of controlling the massif in favor of methods that do not destroy the massif by using hardenable packing.

The choice of technological parameters for gobbing cavities must be determined by the condition of obviating destruction of the earth's surface. Such an approach appreciably

changes methods of assessing the effectiveness of gobbing technology. The problem is to find sections of the deposit that are optimum with respect to geomechanical and economic considerations and that are gobbed by a combined method: loose packing and isolation.

The feasibility of using loose packing and isolation of cavities depends on the extent of utilization of the residual supporting capacity of rock. It is known that when the spans of blocked out sections do not exceed the limiting permissible values for given conditions, rocks may form strong supporting structures. Such sections can be distinguished in a massif by solving the problem

$$\left. \begin{array}{l} L_{ac} \leq L_m < L_{lim} \\ L_{ac} \leq L < L_{lim} \\ H > h_c \end{array} \right\}, \quad (1)$$

where  $L_{ac}$  is the actual span blocked out, m;  $L_m$  and  $L$  are the spans of flat unreinforced blocked out sections of the main and nether roofs, m;  $L_{lim}$  is the limiting span of blocked out sections, m;  $H$  is the depth of mine operations, m;  $h_c$  is the zone of influence of cavities, m.

The limiting span is determined from some formula, such as that of S. V. Vetrov, for structurally inhomogeneous massifs.

The region of applicability of resource-saving technologies with respect to the main criterion—preservation of the surface of the ground—is determined by solving an optimization model by a method of successive trials of options by computer, leaving one parameter unchanged each time while varying the others over prescribed intervals.

Given below are the results of application of the method for determining the area of application of isolation and loose packing for conditions of development of intricately structured deposits of Northern Kazakhstan. Fig. 1 shows a block diagram of optimization.

The spans of blocked out sections that depend on structural-mechanical characteristics of massifs are determined from the formulas (Fig. 2):

$$L_{lim} = 2a = 2d_1 \left( \frac{10R_{comp}}{k_1 \gamma H} - 1 \right), \quad (2)$$

$$L_m = 1.71 \sqrt[3]{\frac{10R_{comp} d_{m2}^2}{K_1 \gamma}}, \quad (3)$$

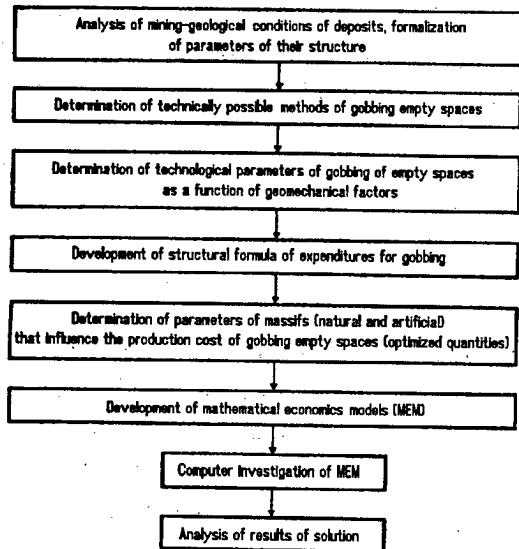


Fig. 1. Block diagram of optimization of technology for gobbing empty spaces

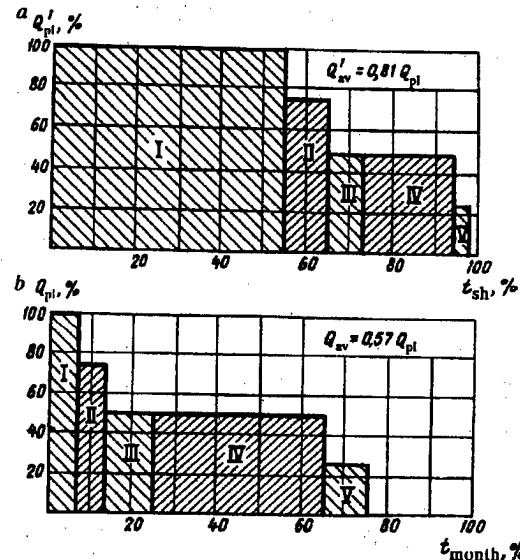


Fig. 2. Diagram for figuring permissible spans of blocked out sections: a—main roof; b and c—nether roofs

$$L = 1 \cdot 49 d_{n2} \sqrt{\frac{10 R_{comp}}{k_1 \gamma b}}, \quad (4)$$

$$L_{sh} = 1 \cdot 49 m d_{n2} \sqrt{\frac{10 R_{comp}}{k_1 \gamma b}}, \quad (5)$$

where  $d_1$  is the averaged horizontal dimension of structural blocks, m;  $R_{comp}$  is uniaxial compression strength, MPa;  $k_1$  is the safety factor;  $\gamma$  is the density of rock in metric tons per cubic meter;  $d_{m2}$  and  $d_{n2}$  are the vertical dimensions of the main and nether roofs, m;  $b$  is the thickness of the nether roof, m;  $L_{sh}$  is the permissible span of the shored nether roof, m;  $m$  is the coefficient of reinforcement of the roof by anchoring.

In formulas (2)–(5), the variable parameters may assume values in ranges of:  $d_1$ —0.2–4.0 m,  $d_{m2}$ —0.2–2.0 m,  $d_{n2}$ —0.1–1.0 m,  $H$ —100–600 m,  $\gamma$ —1.8–3.0 metric tons per cubic meter,  $R_{comp}$ —60–140 MPa,  $b$ —0.25–3.0 m,  $m$ —1–3 m.

The region of application of methods of gobbing is found as the set of values that meet the condition of preservation of the surface of the ground (1). The numerical values of spans with gobbing by isolation are limited to 27 m, and with gobbing by loose packing with separation by firm artificial pillars—to 100 m.

To determine the gain due to gobbing of empty spaces by using resource-saving technologies of isolation and packing with a loose mixture with respect to preservation

of the surface of the ground, calculation is done with respect to the integrated coefficient of extraction of metal with allowance for all process stages up to the hydrometallurgical plant inclusive with respect to national economic and sector-wide prices.

The provisional gain is defined by the expression

$$G = \sum_{t_0+1}^t \frac{(Me_{c.m} + Me_{UL} + Me_{HL}) P_m - E}{1.08^{t-t_0}} - Me_L \cdot P_m, \quad (6)$$

where  $G$  is the provisional gain from working reserves of the deposit with allowance for losses of metal and processing time, rubles;  $Me_{c.m}$  is the metal in the final product obtained by conventional methods, kg;  $Me_{UL}$  is the metal in the final product extracted by underground leaching, kg;  $Me_{HL}$  is the metal in the final product obtained by heap leaching, kg;  $Me_L$  is the total amount of metal lost on all process stages for different technologies of obtaining it, kg;  $P_m$  is the price of metal, rubles/kg;  $E$  is normalized expenditures for obtaining metal in the final product, rubles;

$\frac{1}{1.08^{t-t_0}}$  is a coefficient that accounts for the time factor;  $t_0$  is the when working of reserves is started;  $t$  is the time when working of reserves is ended.

Calculation was done for ores with content of useful component of 0.7, 1.0 and 1.5 provisional fractions of a unit and ten possible combinations of different types of packing in the volume worked out:

Methods of gobbing cavities	Tight packing	Loose packing	Isolation
1	33.3	33.3	33.3
2	66.6	33.3	—
3	100.0	—	—
4	—	66.6	33.3
5	—	100.0	—
6	—	33.3	66.6
7	—	—	100.0
8	66.6	—	33.3
9	33.3	—	—
10	33.3	—	66.6

The calculation assumes an underground method of development with ore processing in radiometric concentration mills and hydrometallurgical plants. The amount of ore routed to the RCM depended on the content of useful components in reserves: first grade 60% of the output, second grade 50%, and third grade 40%.

TABLE 1

Gain from combined method of gobbing mined out space with respect to condition of preserving the surface of the ground (for metal content in ore of 1.5 provisional units)

Technological limits	Volumes of processing, %	Integrated coefficient of extraction, %	Production cost per unit of output, rubles/kg	Expenditures per unit of output, rubles	Profit, thous. rubles		Gobbing technology, %		
					of enterprise	of national economy	firm packing	loose packing	isolation
RMC	42,80	0,84	99,34	2118					
HMP	58,86	0,93	29,86	3074					
Together	107,00	0,89	43,32	5399					
Grand total	100,00	0,89	43,32	5399					
RMC	42,80	0,84	102,18	2210					
HMP	58,85	0,93	30,47	3159					
Together	107,00	0,89	44,55	5552					
Grand total	100,00	0,89	44,55	5552					
RMC	42,80	0,84	99,34	2148					
HMP	58,85	0,93	29,86	3074					
Together	107,00	0,89	43,32	5399					
Grand total	100,00	0,89	43,32	5399					
RMC	42,80	0,84	96,24	2087					
HMP	58,85	0,93	29,08	2990					
Together	107,00	0,89	42,12	5246					
Grand total	100,00	0,89	42,12	5246					

The results of calculations are summarized in Table 1.

Simultaneous use of the results of mathematical modeling in determining the region of application of methods of gobbing and calculation of provisional gain on the planning stage enables prediction of the possible economic advisability of mine development as a function of the method of gobbing cavities, including the volume of utilization of resource-saving technologies: isolation and loose packing with preservation of the surface of the ground.

The gain from using resource-saving technologies as a function of the volume of their realization is determined with respect to the integrated coefficient of extraction on all mining and metallurgical process stages with combination of both technologies of extraction and technologies of gobbing massifs, and runs as high as 5–15% of the value of salable metal.

The gain from combining gobbing methods is also increased by combining conventional mining technology with geotechnology. In combined working of deposits, the ore of highest grade is brought to the surface and processed at the hydrometallurgical plant, and the mined out space is replaced with hardenable packing, which acts as a supporting element with redistribution of bearing pressure.

In relieved sections of the deposit, the ore is crushed and compacted for leaching. In this process, some of it is brought to the surface to create the necessary coefficient of loosening of ore in the magazine. The tailings of underground leaching, which have a strength of as much as 1.0 MPa, are used as hardenable packing.

To calculate the effectiveness of using tailings of underground leaching, compared options of gobbing cavities were calculated with respect to the final product: the value of 1 kg of metal after the hydrometallurgical plant.

TABLE 2  
Economic effectiveness of combined working of different grades of ore

Indices	Production capacity, thous. metric tons					
	300		400		500	
	packing	UL	packing	UL	packing	UL
Cavities formed, thous. m <sup>3</sup>	130	130	175	175	205	205
Rock taken from subsurface, thous. m <sup>3</sup>	130	85	175	118	205	138
Left in cavities, thous. m <sup>3</sup>	—	44	—	68	—	67
Packing of cavities with hardenable mixtures, thous. m <sup>3</sup>	130	86	175	157	205	138
Cost of 1 m of hardenable packing, rubles	6	6	6	6	6	6
Expenditures on hardenable packing, thous. rubles	780	516	1050	702	1230	822
Expenditures on extraction, rubles/kg	28,3	27,5	26,7	26,0	23,7	23,0
General mining expenditures, rubles/kg	39,9	41,2	36,3	37,2	31,2	31,6
IIMP processing expenditures, rubles/kg	21,2	15,3	21,2	15,3	19,0	13,2
Market value of metal, rubles/kg	61,0	56,9	57,5	53,0	50,2	46,1
Economic effect, rubles/kg	—	4,1	—	4,5	—	4,1
Including from the use of UL tailings in packing, rubles/kg	—	1,0	—	1,0	—	1,0
Savings from using UL tailings, thous. rubles	—	264	—	348	—	402

We can see from Table 2 that combined working of deposits with some increase of specific expenditures on subsurface extraction yields rather considerable economic advantages in the course of further processing due to an increase in the content of useful component in the raw material, reducing the production cost of metal by 6–10% as compared with conventional technology. A quarter of the resultant economic effect comes from using tailings of underground leaching as low-strength hardenable packing. The actual savings from using this material for a mine with production capacity of 300,000–400,000 metric tons per year is 250,000–400,000 rubles. The use of 40,000–70,000 m<sup>3</sup> of tailings for packing saves materials, including about 5,000–10,000 metric tons of cement and 60,000–100,000 metric tons of sand per year.

Analysis of the relations found between cost indicators and gobbing technology shows that the economic effect of resource-saving technologies increases with increasing value of the extracted raw material and production volume.

So far, combined gobbing of mined out spaces with employment of the residual supporting capacity of rocks is rarely used. Discontinuation of destruction of the earth's surface, demands for ecologically clean mining operations and scarcity of materials for preparing hardenable packing are setting the stage for increased volumes of combined gobbing of empty spaces.

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## Outlook for Using Underground Leaching Technology With Wells in Working Mineral Deposits

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[Article by V. K. Zabelskiy, candidate of geological and mineralogical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

[Text] The method of underground leaching (UL) with wells is now the predominant technique in uranium extraction. The reason for the extensive use of this method is low production cost (20-30% less than for rock mining—RM), low ( $\frac{1}{2}$ - $\frac{1}{5}$ ) capital investments, and rapid recuperation of investments (1-2 years), convenient working conditions and a high level of automation of the process, and also the capability of acquisition and development of deposits with difficult mining-geological conditions, including considerable depths of occurrence of ore bodies (down to 600-700 m) in flooded levels under high pressure and with extra-balance (for RM) metal contents in ores.

The uranium extraction sector has assimilated a wide gamut of technological approaches to working deposits by the UL method, encompassing technology and engineering for cutting wells under a variety of natural conditions, including low-permeability ores, technology and equipment for supplying and recovering solutions, technology and equipment for processing productive solutions (enriched with a useful component) with very low concentration of the main and associated useful components, and techniques for reclamation of subsurface and surface resources [1].

Exploration and assaying of the geotechnological properties of ores of deposits when using underground leaching technology with wells are handled by specialized geological exploration associations and expeditions in stages with the use of a set of methods of obtaining geotechnological information that is regulated for each stage [2].

Fig. 1 shows a process schematic of an underground leaching enterprise.

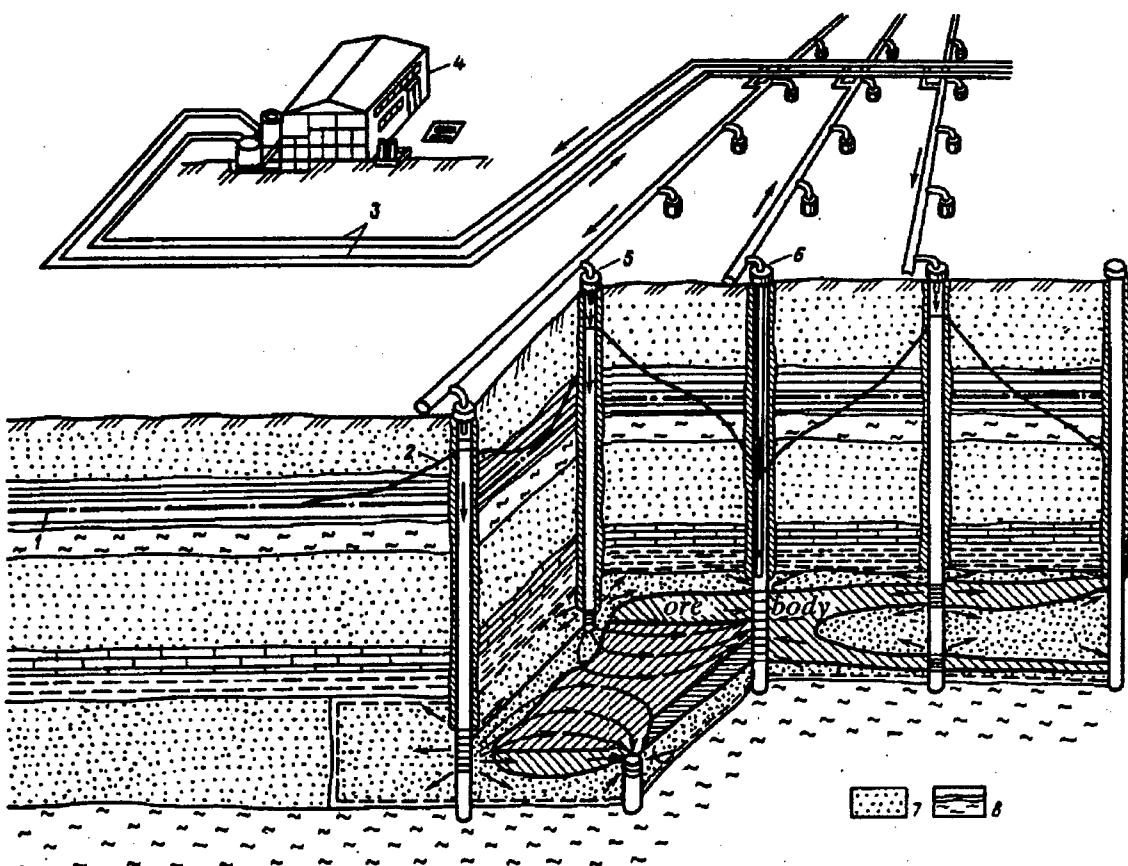


Fig. 1. Basic schematic diagram of underground leaching enterprise: 1, 2—static and dynamic water level respectively; 3—main pipelines; 4—facility for processing productive solutions and preparing working solutions; 5, 6—feed and recovery holes respectively; 7—water-bearing sands; 8—water-bearing rocks

The leaching reagents are fed to the ore zone through a system of injection process wells. The reagent flow that is formed by interaction in the recovery—injection well system moves toward the recovery wells, dissolving the useful component contained in the ores. Productive solutions are fed through a system of collector lines and main pipelines to the processing complex. This consists of a system of settling basins, pumping equipment, and facilities for sorption, desorption, and regeneration of resins and final concentration of output products. After the useful component has been removed, the tailing solutions are spiked and transported for injection to the blocks that are being worked. Extraction of useful component from the underground leaching blocks is monitored by the recovery and initial reserves, and assaying data. Extraction is usually 80–85%. When blocks have been worked out, they are flushed with interstitial water, followed by subsurface and surface reclamation. Thus, underground leaching with wells is done in a closed cycle, and corresponds to basic requirements of no-waste technology.

The main geotechnological link in the process by which leaching solutions are supplied to the bed, and productive solutions are recovered, is a system of injection and recovery process wells.

The selection of well construction is determined by the depth of occurrence of ore bodies and water levels, the composition of the leaching reagents and the accepted technological conditions (arrangement of wells in plan and cross section, rated productivity, type and construction of devices for raising solutions). The designs of injection and recovery wells should be reliable and support the planned yields of recovery and injection, gas tightness and water tightness of the level over the ore.

The casing materials are pipes made of PNP and PVP polyethylene, fiberglass and metal-reinforced plastic, and stainless steel. Pipe diameters are 90–277 mm with a wall thickness of 2–20 mm. Pipes are connected by welded, sleeve and threaded joints. Well filters are selected with consideration of prescribed productivity, granulometric composition of deposits and aggressiveness of fluids. Tubular filters with circular and slit perforation are used, as well as mesh and disk filters. Levels are waterproofed by cementing through injection pipes and cementing devices of various designs. The solution is raised by airlifts, diaphragm pumps, and submersible pump units of type ETsV6–25/40 KhG, ETsV6–10–235 KhG/25, PEN6–240–150, and others. Process wells are drilled by serially produced URB–3AM, 1BA–15V and UBV–600 rigs.

The set of process wells arranged in a certain way and the established procedure of working and retiring them, coordinated in time and space with the controlled chemical-technological process of transferring the metal to solution, filling and reclamation of spent blocks, is called the well system of development.

It includes the following components: the arrangement of wells in plan and cross section; the hydrodynamic state of operation created by controlling recovery—*injection flows*; the geotechnological mode of delivery of reagents and oxidizers during the process.

The uranium extraction industry has accumulated considerable experience in using different systems of development. The main factors that determine the applicability of a given system of underground leaching are the dimensions, morphology and spatial arrangement of ore bodies, material composition, permeability and filtration inhomogeneity of ores and country rock, and the thickness of ore-intruding levels. Various classes of UL systems are used to work ores in the filtration mode. The parameters of systems within the confines of individual classes, sub-classes and groups are optimized on the basis of methods of modeling and predicting technical-economic indicators.

The All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology has developed a methodology, set of algorithms and programs for optimizing the well systems of underground leaching based on deterministic models of forecasting the hydrodynamics and kinetics of the

process with sorting of versions of technological approaches and selection of the optimum version that corresponds to the maximum provisional gain. The kinetic laws used in modeling are determined in the course of laboratory, experimental and experimental-industrial research on leaching.

The optimization algorithm consists of:

selection of modeling facilities based on typing and zoning the deposit with respect to conditions of development;

selection of the method of modeling filtration flows;

determination and adaptation of initial kinetic laws relating to the structure of filtration flows;

selection of a base version relative to which alternative technological approaches are compared;

informational support of technical-economic calculations;

calculation of yearly overhead disbursements and capital investments based on cost parameters;

analysis of the influence of natural and technological factors on the economics of the enterprise;

refinement of the mathematical economics model;

selection of the optimum technological approach based on maximum provisional gain and maximum normalized expenditures. The methodology of optimization of engineering approaches has been tried in scientific-technical, technical-economic and design developments on more than 30 different types of deposits being worked by underground leaching well systems.

Hydrodynamic, physicochemical and physical methods of process intensification are used to raise the level of extraction of the useful component from mineral deposits, and to reduce losses and dilution of ore and the expenditure of reagents in UL.

Methods of acting on  
ore bodies and seams

Hydrodynamic

Technological methods

Pulsating mode of well operation. Change of the direction of motion of solutions in the process of leaching (reversal, alternating directions of flow, etc.

	Interval working of zones of mineralization with different permeability
	Flooding of seams and ore bodies
	Forced pumping of reagent into seam
Physicochemical	Preliminary acidulation of seam
	Adding oxidizing reagents to the process
	Oxidizing ore in the mode of injecting gas-saturated solutions (gas saturation at each well and centralized)
	Oxidizing ore in mode of displacement of interstitial waters
Physical	Creating zones of elevated permeability by interval hydrofracture
	Creating zones of elevated permeability with extended collectors by hydrofracture
	Acting on the filtered zone and ore body by high-density and low-density currents
	Acting on the filtered zone by pneumoacoustic and other methods

Hydrodynamic and physicochemical methods of intensification are used on deposits with ordinary permeability, and physical methods are used where permeability is reduced [3].

The use of UL systems that account to a maximum degree for the natural features of deposits, and various methods of process intensification have enabled development of highly effective mining technology.

A crucial aspect of technology is assurance of safe working conditions and preservation of the environment. The major contaminants in UL are the active solutions, and products of leaching and processing of solutions. The concept of preservation of the environment includes: a set of measures to monitor the state of the environment, engineering approaches that ensure safe exploitation of deposits, and what is most important, reclamation of the surface and subsurface after working fields by UL. Reclamation strategies are used in some combination that depends on the initial state of the waters of productive levels. Most capital intensive is a system of engineering measures for reclamation of aquifers with potable water.

Preliminary analysis of the solubility of basic industrial minerals in various acids and other solvents has enabled differentiation of their main groups with respect to conditions of utilizing geotechnological processing methods of working deposits.

The following are distinguished in the basic formulation: the group of water-soluble (at normal temperature or in hot water) minerals, acid-soluble and soluble in solutions of strong oxidizers (based on active chlorine, bromine, and so on), or of cyanide and other

*Grouping of basic industrial minerals by geotechnological properties*

Classification of technological properties

I. Water-soluble

halides	sulfates	hydroxides	borates
halite,	polyhalite,	salt peter,	borax,
sylvite,	mirabilite	soda niter	hydroboracite
carnallite		potassium nitrate	boranatro-calcite

II. Acid-soluble

- a) Soluble in weak sulfuric and other acids      b) In concentrated sulfuric and other acids      c) Including with the use of active oxidizers, microbiological processes

Classification of technological properties

oxides

uranite,  
fumigating  
resin,  
blacks  
salts, vanadium

thornbermite,  
autunite,  
tyuyamunite,  
cornatite

of carbonic acid  
siderite,  
malachite  
azurite,  
smithsonite  
phosphates  
phosphorite,  
apatite

oxides

cuprite,  
tenorite,  
pyrolusite,  
hematite,  
ilmenite,  
rutile,  
cassiterite,  
malachite  
azurite,  
smithsonite  
cinnabar

sulfides

bornite,  
chalcosine,  
covellite,  
chalcopyrite,  
molybdenite,  
sphalerite,  
pyrrhotite,  
pentlandite,  
gallenite,  
cinnabar

thio salts

proustite,  
boulangerite,  
smithsonite

III. Soluble in cyanides or a composite of reagents, using hard oxidizers  
native metals

gold,  
platinum,  
silver

reagents. Within the second group, three main subgroups of minerals can be distinguished in order of decreasing solubility. Most technologically feasible is the group of oxides and salts of weak acids. In this subgroup are practically all uranium minerals that are suitable for underground and heap leaching. Oxides of copper, manganese and iron (top row of subgroup IIb) can be leached by using sulfuric acid (high concentration)

reagents with oxidizer additives; sulfide minerals (subgroup IIb) require the use of active oxidizers, thermal methods of preparation, or microbiological leaching methods. Most resistant to standard sets of reagents (sulfuric acid with small additives of oxidizers) are sulfides of the bottom row of this subgroup and native metals. Therefore cyanide reagents or composite reagents based on very active oxidizers (chlorine, bromine) are used in plant and outdoor gold and silver leaching facilities.

With respect to the degree of accessibility of mineral forms for leaching reagents three main groups of deposits are distinguished:

with porous ores or highly soluble mineral forms (deposits with water-soluble minerals, uranium deposits, zones of oxidation of copper and gold ore deposits, placer deposits of manganese oxide ores, grainy phosphorites);

with slightly porous ores, but having properties tending to increase permeability due to low-power physical effects (hydrobursts, microblasts, heating of a seam, and so on). These are zones of oxidation of deposits of iron, copper, permafrost gold placer deposits, copper sandstones, some phosphorite deposits;

rock ores.

The third group of deposits requires special blasting preparation for leaching, and drilling through certain volumes of driftage. Deposits of the first two groups are most suitable for using UL with wells.

In addition to uranium deposits, an examination has been made of gold placer deposits, gold ore deposits in zones of oxidation of primary sulfide ores, phosphorite, manganese and copper deposits, and some others as objects for evaluating the possibility of using this technology.

The question of developing scientific-technical proposals on trying UL on USSR gold ore deposits has been formulated on the basis of analysis of the cumulative experience of the rare metals industry in assaying and working uranium deposits, the available scientific and engineering potential of the sector, and the practical capabilities of transferring it to the national economy; data about the wide-scale use of geotechnological methods of ore processing (more than 50 heap leaching enterprises in the United States and Canada); positive results in heap leaching of gold on some Soviet facilities; results of laboratory experiments on gold leaching done at several institutes, and also preliminary analysis of the raw material base of gold ore deposits that has shown the presence of permeable ores in some industrial types of deposits.

Of the eight industrial types of deposits that are basic for gold extraction worldwide, two meet requirements for natural conditions on applicability of UL technology with wells (natural permeability, complete or partial flooding of ore bodies and occurrence of free

gold). These are zones of oxidation of deposits of gold sulfide formation widely prevalent on the territory of Kazakhstan, and placer deposits of gold in the Northeastern and Maritime regions of the Soviet Union.

The main problems in realization of the formulated task are selection of ecologically non-intrusive reagents that provide an acceptable level of subsurface gold extraction (75–80%), development of engineering techniques for selective melting of frozen ores, and increasing the natural permeability of ore that is partly rock. Specialists of the All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology have developed a composite of effective and ecologically safe non-cyanide leaching reagents with trials on experimental scales. For trying technology of underground leaching of gold, two basic geotechnological process arrangements have been developed that correspond to natural conditions of the differentiated industrial types of deposits.

Formulation of industrial field trials should be preceded by a series of laboratory experiments on static and filtration leaching to obtain characteristics on extraction of gold into a solution and the consumption index of the process, as well as experimental filtration operations on evaluating the permeability of the rock massif.

#### *Process arrangement for trying underground leaching of oxidized ores*

Fig. 2 shows a schematic diagram of an experimental section for trying technology of underground leaching of oxide ores with wells.

The section consists of facilities of a geotechnological and processing system. The geotechnological system includes 12–18 process wells, 6–8 water injection wells, 4 observational wells and 1–2 water supply wells. The total number of wells ranges from 18 to 24. The purpose of the water injection wells is to try ore bodies that are not flooded.

The process wells are supposed to be arranged in rows with parameters of  $10 \times 20\text{--}25$  m. The capacity of return wells is  $3\text{--}5 \text{ m}^3/\text{hr}$ , and of injection wells is  $2.5\text{--}3 \text{ m}^3/\text{hr}$ . Provisions are made for shifting the balance with excess of return over injection to limit spreading of solutions.

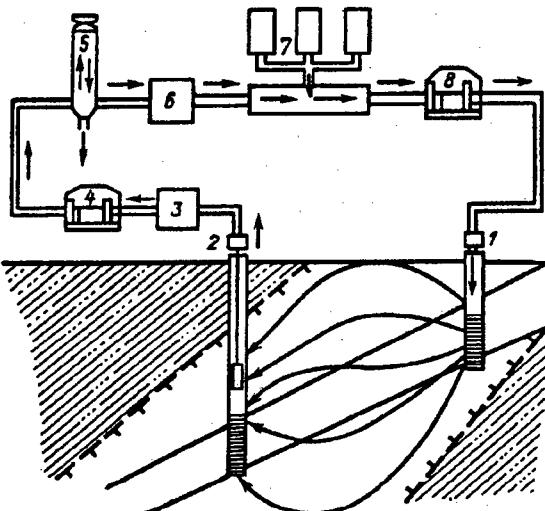


Fig. 2. Schematic diagram of experimental UL section: 1, 2—*injection and return wells respectively*; 3—*unit for cleaning productive solutions*; 4, 8—*pumping stations*; 5—*processing unit*; 6—*unit for cleaning solutions following sorption*; 7—*unit for preparing working solutions*

The processing system, of modular design, consists of units for: cleaning productive solutions, sorption, cleaning solutions following sorption, regenerating solutions, pumping, preparation of solutions, and the lines that connect these units. The capacity of the system reaches 30–50 m<sup>3</sup>/hr. The cost is roughly 750,000–900,000 rubles. Provisions have been made for developing versions of sorption on ion exchange resins and activated charcoal. Completion of experimental work is to be followed by reclamation of the subsurface, water, and surface, with drilling of monitor wells for assessing the extraction of gold from the ores.

After 6–8 months of operations, the process should result in 60–70% extraction of subsurface gold, and should provide the initial data for planning an experimental-industrial system and underground leaching facility.

#### *Process arrangement for trying well technology of gold leaching from placer deposits*

Tentative analysis of natural conditions of placer deposits of Siberia, the Urals, the Northeast and the Maritime territories in combination with the cumulative practical scientific experience of the rare metals industry has revealed major components of possible well technology for leaching gold from deposits of placer type, including: engineering techniques for opening productive levels, casing of process wells, facilities for raising the solution, systems of working the deposits, the transportation complex and measures of environmental protection when working placers in partly frozen rocks. When working placers in the zone of perennially frozen ground and permafrost, methods have to be developed for selective melting of country rock and trials of basic hardware for raising the solution under conditions of low temperatures on experimental sections.

Fig. 3 shows a diagram of placement of the wells on a section of underground leaching of gold from placers under conditions of permafrost.

The procedure used in experimental operations includes:

opening the ore seam by process wells in a grid of 30–35×10–15 m'

drilling observation wells;

preparing the ore seam for UL by hydrofracturing or other methods of thawing. This creates an initial channel for filtration of the reagent in the base of the ore seam that systematically widens as leaching proceeds;

direct underground leaching of gold from the ore seam by supply of reagent with variable temperature, resulting in thawing of the seam to its roof. Provision is made for creation of excess pressure in the injection wells to extract the solutions to the surface in the return wells;

reclamation of the subsurface, including (depending on the reagent used) a method of neutralizing residual solutions or displacing them from the worked out space, followed by filling with clean water. In the latter case, the residual solutions are spiked and used for leaching new blocks.

The process of selective thawing of the ore seam along hydrofracture cracks is combined with leaching of the useful component. The capacity of the return wells is 7–10 m<sup>3</sup>/hr, and of injection wells is 5–7 m<sup>3</sup>/hr. The capacity of the section with respect to solutions reaches 30–50 m<sup>3</sup>/hr.

Optimum parameters of the UL process in permafrost deposits are determined by simultaneous solution of differential equations of heat transfer, leaching kinetics, and filtration continuity, using economics criteria. The number of process operations is reduced when working partly frozen placers.

Approximate expenditures for experimental operations are 500,000–800,000 rubles. This arrangement is currently being realized at a placer gold deposit in Siberia.

The foregoing trial arrangements in application to gold ore deposits are a fundamental component of technological approaches and can be used in some modification for other minerals.

Laboratory and field experiments to prepare data for technical-economic studies of the feasibility of doing experimental-industrial research on leaching are currently in progress for deposits of phosphorites and copper ore. In these experiments, 80–85% levels of extraction from ores are being attained, which determines the positive outlook for using geotechnological methods.

### Conclusions

1. Introduction of the method of underground leaching into the practice of extraction of rare metals has enabled operations on deposits with difficult mining and geological

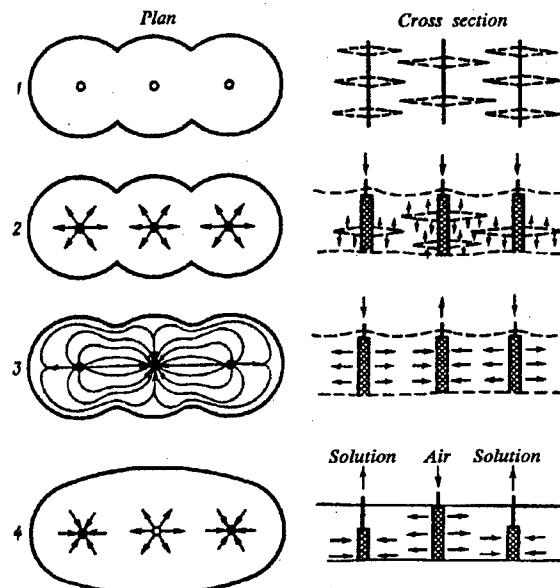


Fig. 3. Sequence of preparation, development and reclamation of placer confined to permafrost zone by UL systems with wells: 1—drilling of process wells, hydrofracturing; 2—melting with heated solutions; 3—UL in thawed zone; 4—reclamation with displacement of residual solutions

conditions and low-grade ores, providing the entire raw material base of the sector and dramatically increasing the technical-economic indicators of extraction.

2. Preliminary comparison of the solubility of minerals in acid solutions has revealed a group of minerals for which well technology of underground leaching can be used, and has enabled differentiation of these minerals with respect to the conditions of application of geotechnological methods of working deposits.
3. Analysis of mining-geological conditions of gold ore deposits suggests that a certain number of these deposits can be worked by the method of underground leaching.
4. Basic process arrangements have been developed for trying ores according to location with allowance for a wide range of variation of natural conditions of deposits of various minerals.

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## Special Methods of Geotechnological Preparation

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[Article by K. N. Koshkolda, candidate of technical sciences, Ye. V. Goncharko and N. N. Chesnokov, scientists, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

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[Text] Expansion of the field of application of mining by systems with wells has necessitated development of methods of preparing ore beds and intensifying technological processes of extracting minerals.

We take methods of preparing ore beds or sections of beds to mean technological measures that selectively change the filtration properties and strength characteristics of the ore massif or country rock to create optimum conditions for carrying out the process of extracting the useful component and observance of ecological requirements. Methods of intensification accelerate mass exchange processes when forming productive solutions and process pulps.

Special methods of preparing ore beds are subdivided with respect to final purpose into three functional groups: methods of localizing the zone of formation of productive solutions and pulps; methods of increasing the permeability of ore beds; methods of loosening the ore mass. These methods are based on high-pressure hydraulic action (HPHA) on the ore mass or country rock.

When there is considerable horizontal or vertical spreading of fluids and pulps, resulting in non-productive inputs of working fluids, losses of useful component and extensive contamination of surrounding rock, artificial seepage-resistive shields should be created to localize zones where geotechnological processes will take place and where leaching and productive solutions or pulps will be transferred.

In the case of underground leaching, for example, it is most promising to make HPHA seepage-resistant shields by using hydrofracture and filling the resultant cracks and cavities with hardenable material. When making artificial shields in high-permeability country rock, the isolating material can be injected by HPHA in the mud-jacking mode (without reaching the pressure of hydrofracture of rock).

To increase the natural permeability of the ore mass and create artificial permeability, along with the action of blasting in remote loosening operations in which rocks are cracked without breaking, the most promising technique is interval hydrofracturing of rock of the ore interval, followed by packing filtering material into the resultant cracks. Practice in using this method shows that in some cases, permeability of the massif that is sufficient for underground leaching can be achieved by HPHA without packing cracks and holes.

Various technological arrangements for HPHA that preloosen rock mass, optimize conditions of formation of the slurry and localize the zone of pulp formation correspond to solution of problems of intensifying well hydromining (WHM).

Of the great number of known methods of intensifying geotechnological processes, most highly developed at the present time are those that use electrophysical action on the pre-bore zone of underground leaching production wells and on the ore mass as a whole. The application of AC and DC electric fields to the filter zone of return wells in UL increases well output due to a sharp reduction of mud jacking. Moreover, experience in using this effect shows an increased concentration of useful components in the productive solutions. In WHM, electric action by high-density currents preloosens rock and intensifies the intake of ore material into extractive zones or chambers.

An example of the use of HPHA for creating artificial seepage-resistive shields to localize UL working solutions is a section of a hydrogenous deposit including three hydrofracturing wells (to create the shield), three process wells (two injection and one return) and three observation wells. Within the limits of the section, mineralization is localized in an interval of 115–120 m, and is confined to the upper part of the productive level with coefficient of filtration  $K_f = 4$  m/day. The lower aquiclude can be traced to a depth of 160–170 m. The main problem was to provide directed filtration of leaching solutions within the limits of the ore body by creating an artificial shield in the interval of 122–124 m. Hydrofracturing wells were made to a depth of 122 m, and were equipped with a steel protective pipe column with diameter of 114x7 mm. A TsA-320A pumping unit was used for hydrofracture and for injecting isolating material into the seam (clay mud with density of 1.1–1.15 g/cm<sup>3</sup>). The hydrofracture pressure in all three wells was  $P_h = 5.0$  MPa, and the pressure of the clay mud was 2.0 MPa. A total of 60 m<sup>3</sup> of clay mud was injected. To check the distribution of isolating material, the clay mud was treated with a dye marker before injection. From a core taken during boring of the process and observation wells, it was established that the filtration properties of rocks drop to  $1/6$ – $1/10$  in the zone of the shield. The radius of extension of the shield was

15–20 m. The distribution of leaching solutions was monitored by hydrochemical testing with induction logging in the observation and process wells. It was found that filtration of solutions occurred above the artificial shield (Fig. 1), enabling a reduction by a factor of 1.5–2 in the expenditure of sulfuric acid leaching reagent during working of the section.

On a section of another deposit, creation of an artificial aquiclude was dictated by the necessity of excluding from the hydrodynamic scheme unproductive but highly permeable (21 m/day) gravelites 20 m thick underlying ore-bearing clay sandstone ( $K_f = 7$  m/day). To create the shield, HPHA was done in every third well 235 m deep and 168 mm in diameter in the hydrofracture mode ( $P_h = 6$ –9 MPa with subsequent clay mud jacking (100 m<sup>3</sup> per well). The resultant shield was pierced by five wells from which cores were taken. It was established that with a radius of extension of the shield of 25 m and thickness of 0.2–0.7 m, the coefficient of filtration of gravelites in the mud-jacking zone was reduced to 0.95–2.0 m/day.

A mechanism is needed for regulating permeability when working low-permeability ores (copper, gold). A method of interval HPHA is used to prepare copper ores localized in granodiorites 6 m thick with initial coefficient of filtration of 0.0001 m/day. On the section, a special well was drilled down to a depth of 200 m, fitted with a processing column of steel pipe 143 mm in diameter cemented up to the well head. To do HPHA work, each of the six project intervals (Fig. 2) was pierced by jet perforation. HPHA work was done from the bottom up with isolation of the worked out lower interval by a sand plug. The injection of process water (10 m<sup>3</sup> in each interval) was done in the hydrofracture mode ( $P_h = 19.5$ –20.0 MPa) with subsequent high-pressure injection (5–12 MPa) at a rate of 10–15 l/s.

As a result of creating artificial zones of elevated permeability, the massif is prepared for underground leaching of copper ores on the section.

The first stage of instituting WHM of deep high-grade iron ores of KMA [not further identified] has shown that without the use of methods of preparation and intensification, the effectiveness of this technology is low, as the production well is not optimally loaded from the technical-economic standpoint. Here HPHA can be used in all possible technological arrangements: interval loosening of ores that are difficult to wash out; intensification of pulp-lifting by forced movement of ores toward the extraction zone and chambers (Fig. 3); displacement of loose flowrock ores by injecting high-viscosity agents into the massif.

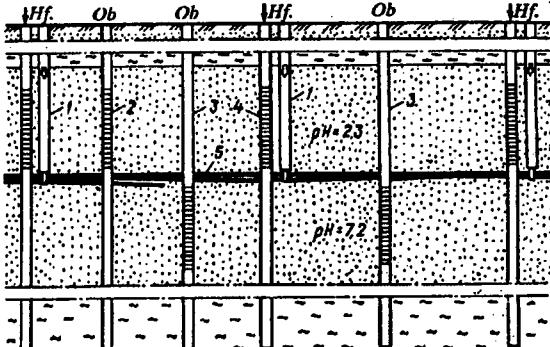


Fig. 1. Artificial filtration shield created by HPHA:  
1—hydrofracture well; 2, 3—observation wells for productive and unproductive intervals respectively;  
4—process well; 5—seepage-resistive shield

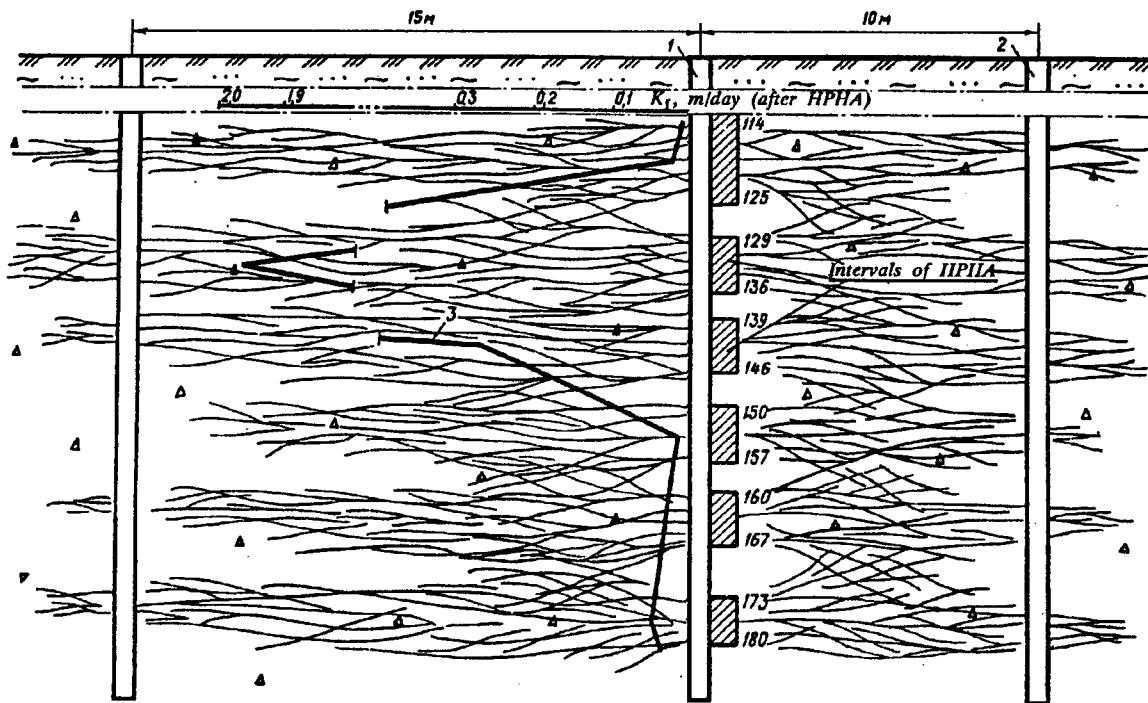


Fig. 2. Zone of elevated permeability produced by interval HPHA: 1—HPHA well; 2—observation well; 3—depth dependence of permeability after HPHA ( $K_p$ , m/day)

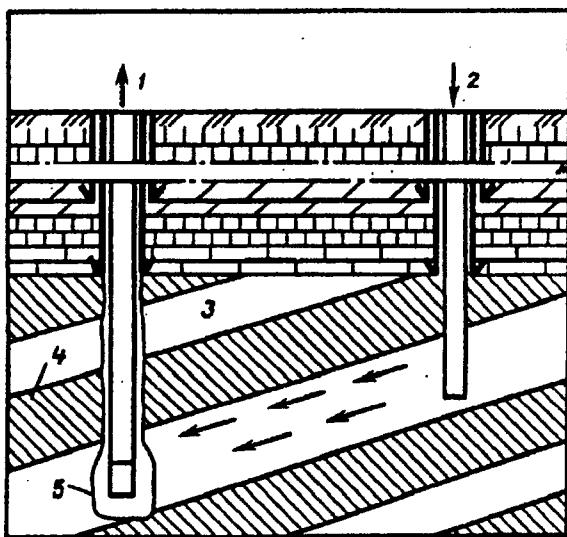


Fig. 3. Version of technological arrangement for intensifying WHM of iron ore: 1—production well; 2—HPHA well; 3—loose ore; 4—ore that does not wash out easily; 5—extraction zone (chamber)

Employment of these arrangements increases the load on the well by a factor of 1.5–2, and reduces the production cost of extracting inexpensive ore (15–20 rubles per metric ton) by 30–35%, which is especially effective when there are considerable reserves of iron ore subject to working by WHM.

A salvo gun perforator has been developed and tried under industrial conditions for creating filters in the casing pipes of process wells, mud removal, and increasing output or water-intake capacity. The operating principle of the perforator is based on the piercing action of bullets shot from radial channels of the perforator as by explosion of a detonating cord in the main channel. The perforation density and shooting interval per lowering-raising cycle are regulated during charging of the perforator, and have ranges of 1–50 holes/m and 0.5–5.0 m respectively. The

diameter of holes pierced into polyethylene columns is 2–5 mm. The table summarizes the results of opening casing columns of low-pressure polyethylene pipes and disk filters.

Results of opening of low-pressure polyethylene pipe casing columns and disk filters

Index	Wells					
	1	2	3	4	5	6
Column diameter, mm	140	140	140	140	110	110
Filter present	Yes	Yes	No	No	Yes	No
Filter spacing, m	130–133	129–135	—	—	121–127	—
Interval between breaks, m	127–129	131–134	161–167	160–166	119–121	126–135
perforation density, holes/m	64	36	128	128	64	64
Productivity, m /hr:						
before perforation	1.5	2.6	0	0	0	0
after perforation	3.0	6.6	6	1	2	4.5

Note: Breaking was done by bullets 6 mm in diameter.

A program of experimental work relating to electrical action on the filter zone of process wells provided for intensifying the operation of two hydrodynamic cells of an underground leaching section by low-voltage alternating current. Within the confines of the section, the depth of the basement of the productive level was 240–245 m. The thickness of the productive level, comprised of gravelites, sandstones with clay cement and low-permeability aleurolites, is about 30 m;  $K_f = 0.1\text{--}5 \text{ m/day}$ .

Action on the massif was through a three-electrode arrangement with one electrode in each cell (Fig. 4) at voltage of 60 V and current of up to 25 V.

As a result of using the method, the productivity of return wells was increased by 30%, the water-intake capacity of injection wells rose by a factor of 2.4, and the content of useful component in productive solutions increased by 20–40%.

Experience in assimilating the method of electrical action has enabled determination of the region of effective utilization in underground leaching. The prospects for using the method of electrical action in other fields of geotechnology (for example to loosen the ore mass in WHM of iron ore, diamond-containing and gold-containing rocks) are now being studied.

Thus, methods of preparing ore beds and intensifying processes of extraction of useful minerals by geotechnological methods enhance the effectiveness of utilized mining systems, and in some cases are basic for expanding the field of application of progressive extraction technology.

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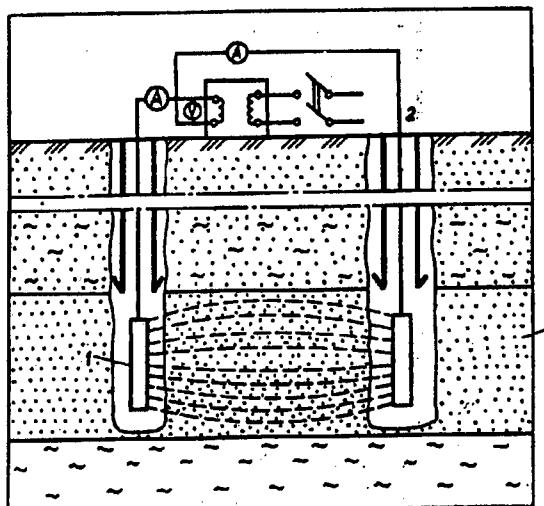


Fig. 4. Intensifying underground leaching processes by low-voltage alternating current: 1—electrode; 2—process well; 3—productive level

## Solution of Ecological Problems of Muruntau Open-Pit Mine

927F0057A Moscow GORNYY ZHURNAL in Russian No 7, Jul 91 (signed to press  
18 Jun 91) pp 56-57

[Article by V. N. Sytenkov, candidate of technical sciences, Navoiyskiy Mining-Metallurgical Combine]

UDC 622.807.2:622.271.3

[Text] A gold deposit located in a region with desert climate is being worked by the Muruntau open-pit mine. The volume of the bowl of the pit at the present time is 700 million m<sup>3</sup> and the depth is 250 m, the projected final depth being 600 m. The main source of contamination of the atmosphere in the pit is truck transport. While other sources are important (e.g. blasting operations with periodic massive emissions of harmful materials and dust), they are nevertheless of secondary significance. On the whole, we have treated the problem of normalizing the atmosphere in the pit as a component part of the problem of the environment, including human habitation. In addition to harming the environment, dust and gas emissions create conditions that are hazardous to workers in the pit with respect to the gas load of the air, resulting in temporary work stoppage. Down time of excavators for this cause was 3500 hours at the Muruntau mine in 1990.

Forecast down time for deep open-pit mines in our nation exceeds 22% of the year's time, and compensation requires an increase by  $\frac{1}{3}$  in the number of working faces, and by 40% in capital investments [1]. Efforts undertaken over the last 10-15 years have not brought us one step closer to solving this problem, as the directions that have been taken to reduce pollution of the environment with dust and gas from open-pit mines [2, 3] have the following disadvantages:

in working out protective measures, major emphasis is given to protection of the atmosphere by reducing the harmful impact of existing equipment, while the introduction of low-toxicity mining technologies has been put in second place;

proposed approaches do not reduce contamination of the atmosphere of pits to normative levels, and are aimed primarily at the space within the pit, which is detrimental

to the ecological situation beyond its confines (e.g. blowout of dirty air in artificial ventilation);

expenditures on normalizing the atmosphere of mines add to the output production cost;

there is a lag in introduction of scientific and engineering advances, and the capabilities of existing technologies and mining facilities are not completely utilized;

there has not been enough research into processes of formation of the dust and gas conditions of open-pit mines and the way that they are interrelated with mining production technologies, or into processes that take place in the atmosphere of pits when attempts are made to intensify air exchange by engineering approaches;

the impact of ecological factors on the health of miners of various trades is not completely evaluated;

there are no effective systems that give information about the degree of contamination of the atmosphere of pits and the surrounding natural environment.

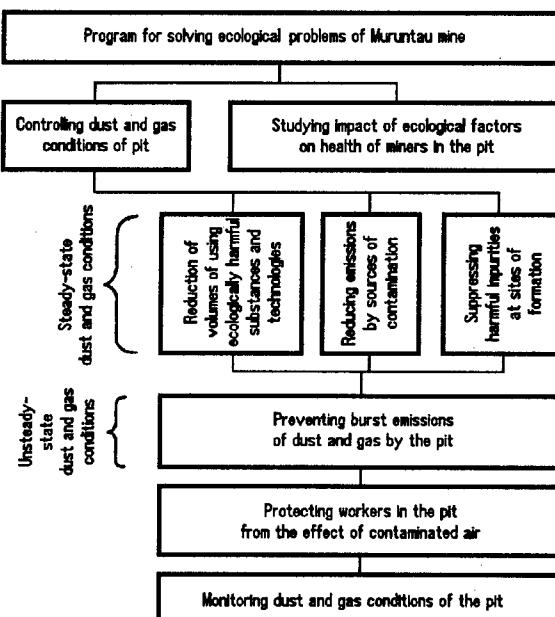
Critical analysis of research has resulted in development of a comprehensive program for solving ecological problems of the Muruntau mine (see block diagram) by controlling dust and gas conditions. The specifics of the program are as follows:

development of engineering facilities that support operation of the pit regardless of the state of its atmosphere;

focused implementation of the results of research already completed on mining technology and integrated utilization of raw material;

reexamination of priority areas in current studies, and inclusion of questions of investigating the influence of ecological factors on the health of miners.

With respect to the nature of entry of dust and gas into the environment, operations in the pit are differentiated into periods with steady-state dust and gas conditions (influx into the environment relatively uniform) and unsteady-state conditions (influx by bursts). The



Comprehensive program for solution of ecological problems of Muruntau mine

dust and gas conditions are controlled by reducing the volume of use of ecologically harmful materials and technologies, reducing emissions of sources of contamination, and suppressing harmful impurities at sites of formation.

During the steady-state period, technological approaches are used as the main methods, and engineering approaches are used as supplemental only in working zones (excavator faces, truck roads) and at work sites (suction plants at transshipment stations of cyclic-flow systems).

Technological approaches are based on such methods as: optimizing the basic parameters of the pit through the use of computer-aided design technologies, which for the Muruntau mine means: a reduction in the overall volumes of extraction, and accordingly the emissions of dust and gas by 10–12%; removal of the load from the pit by organization of ore extraction beyond its confines on technogenic deposits along with processing of low-grade ores by the method of heap leaching, which reduces the volumes of mining and transport work in the pit; redistribution of the volumes of extraction of rock by temporary holding with the use of ecologically cleaner transport (cyclic-flow systems); combining transportation of rock by conveyors with the process of size grading and isolation of the required fraction, in particular for construction purposes; improving the effectiveness of using already available technologies and equipment, e.g. through a 20% increase in the coefficient of utilization of dump trucks by hauling ore in one run from the inner zones of the pit to outside stockpiles, and rock from the flank zones of the pit to transshipment stations of the cyclic-flow system on the inside.

Engineering approaches that have been introduced into mining operations provide for: dust suppression by UDM-40A universal road machines developed and manufactured on the basis of BelAZ-548A dump trucks that are used in watering down roads and irrigating working faces (tank capacity 43 m<sup>3</sup>, giant jet range of 70–75 m with water flow rate of 0.055 m<sup>3</sup> per m<sup>2</sup> of irrigated area); passing exhaust gases through rock in the bed of the dump truck (reducing emissions of soot, nitrogen oxides and carbon by 40–60% within 5–6 minutes after starting motion).

During the period with unsteady dust and gas conditions, the measures used for the period with steady-state conditions should be supplemented with engineering approaches of pit-wide dust and gas suppression. This is because the burst emissions that take place after mass blasting and cessation of calm periods and inversions, when considerable masses of dust and gas are blown out of the bowl of the pit in a brief span of time, can be prevented only by localizing and settling, and that on the scale of the entire pit. In our opinion, the use of various pit-wide systems of artificial ventilation and intensification of air exchange to prevent pileup of dirty air in the bowl of the pit holds no promise, and we have made no such provision.

An attempt has been made to settle dust and gas inside the bowl of the pit by using NK-12V blowers to disperse water into the atmosphere. The result is a reduction of pollutants

in the zone of water mist, which is completely natural (during wet and foggy weather, there is almost no dust or gas in the atmosphere of the pit) and is confirmed by practical operations in other pits [4]. However, for pits with such dimensions as the Muruntau mine, the use of NK-12KV, AVK-35 and other blowers is unjustified from the standpoints of energy and ecology. For these purposes, other less energy intensive and more effective facilities should be used, and until then the only way to reduce burst emissions of dust and gas is to stop operations, but only for the purpose of protecting the environment, and in particular, nearby centers of population.

Operation of the pit regardless of the state of its atmosphere is supported by using facilities that protect workers from the effects of contaminated air, which is the logical culmination of efforts to normalize the dust and gas situation at work sites. for this purpose, the SPGO-1 dust and gas cleaning system has been developed, tested, and is being intensively introduced on BelAZ dump trucks and excavators. This system removes dust, soot, nitrogen and carbon oxides, and organic compounds from air before it enters the cab. For ten times the maximum permissible concentration, the degree of cleaning is 96-97%. The productivity of the facility is 100 m<sup>3</sup>/hr, power consumption 0.8 kW, mass 98 kg. Next in line is development of self-contained air cleaning sources for miners who have to work outside the cabs of mining machines.

In the area of monitoring dust and gas conditions, the thrust is on development and introduction of express-analysis instruments. An attempt to use lidars has also been undertaken that has shown a good outlook for their application in non-contact determination of concentrations of pollutants in the atmosphere of pits and beyond their limits.

Thus, in dealing with ecological problems of the Muruntau pit, the main directions are: controlling dust and gas conditions of the pit by technological approaches; protecting workers in the pit from the effects of polluted air; evaluating the influence of ecological factors on the health of workers in the pit; developing and introducing methods and means of express-analysis of concentrations of pollutants in the atmosphere of the pit and beyond its limits.

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## Housing Construction in the Vicinity of Mining Enterprises and Questions of Radiation Safety

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[Article by V. N. Mosinets, doctor of technical sciences, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology, Yu. N. Soroka, candidate of technical sciences, and A. I. Molchanov, Geophysicist Mining Engineer, Ukrainian Affiliate, All-Union "Order of the Red Banner of Labor" Scientific Research Institute for Preliminary Study and Design of Industrial Technology]

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[Text] The current stage of development of society is characterized by resolute attention to issues of environmental protection, human health and life. The environs of mining enterprises are frequently among sites with technogenically destroyed natural environment. In connection with the accumulation of production wastes on the surface of the ground and their involvement in processing and utilization in the national economy, these regions are a zone of potential contamination by natural radionuclides. One path of such contamination is the use of wastes of extraction and processing of mineral raw material in construction (barren rock of spoil banks, slags of metallurgical plants, ash from heat and electric power stations, tailings from concentration of ores of ferrous and nonferrous metals). The main constraint on the use of production tailings in housing construction with respect to the radiation factor is concentrations of natural radionuclides Ra-226, Th-232 and K-40 exceeding those set by Radiation Safety Standards NRB-76/87.

However, despite the existence of such a constraint, not only most production waste, but also most specifically quarried construction material is not checked for the content of natural radionuclides. As a result of the uncontrolled use of rock in construction, situations have been brought about in some towns and cities of the nation where the populace receives annual doses of irradiation that exceed the standards for a limited part of the population of category B in accordance with NRB-76/87. This considerably raises the risk of onset of stochastic effects among the populace (an increase in the oncological

and other illnesses). Leading radiation factors in this context are elevated contents of radioactive gases radon-222, radon-220 (thoron), and their short-lived decay products. Man receives more than half of the annual dose of irradiation due to all natural products from air irradiating the lungs with these gases [1].

Here we are speaking of radon and thoron that enter the house from materials used in the structural components of buildings. However, this is not the only way that radon can enter a house. It may also enter with the gas flow from soils of the building foundations. This flow may vary, depending on the geology of the region. In some cases, it causes most of the entry of radon-222 into the house. For the environs of mining enterprises there is an unambiguous tendency toward an increase in the radon flux density from the surface of the ground, which accordingly causes an elevated concentration of radon-222 in buildings. This is because the buildings of mining towns are often located over mine works that are not far underground and are aerodynamically connected to the atmosphere. During mining, stresses are set up in the rock massif that correspond to loosening of rocks, elevated release of radon-222 and its emergence at the surface of the ground. This trend is especially pronounced for ores and country rocks that are genetically associated with minerals of uranium and thorium.

Radioactive gases radon-222 and thorium-220 are formed as a result of radioactive decay of radionuclides of the uranium and thorium series radium-226 and radium-224 that are present to some extent in the soil, rocks and construction materials. Studies of recent years [2] have shown that for people living in some houses where the most favorable conditions are brought about for accumulation of the radioactive gases radon and thoron, individual doses of irradiation of the lungs may reach threatening levels equal to 1 sievert per year. The dose limit for the lungs for a limited part of the population (in accordance with NRB-76/87) is 0.015 sievert per year. It is no accident that in some countries like Sweden, Finland, Denmark, Great Britain, the United States and Canada, research has already been in progress for about 10 years in the ranks of government programs to find and rehabilitate such buildings.

In Great Britain alone, such studies have revealed 20,000 buildings in which the lungs of residents were exposed to a dose of more than 0.165 sievert per year [3].

In the USSR, the wide-scale search for buildings of unfavorable condition with respect to the radiation factor was started comparatively recently.

In connection with the necessity of dealing with the housing program, many unconventional materials have been brought into the sphere of operations of construction organizations. Among these are gangue, and wastes of coal enrichment and metallurgical production, which in some cases have a high content of natural radionuclides (NRN) (Table 1).

TABLE 1  
Average concentrations of natural radionuclides  
in rocks and some production wastes [4]

Type of rock or material	Concentration of radionuclides, Bq/kg		
	<sup>40</sup> K	<sup>226</sup> Ra	<sup>232</sup> Th
<b>Volcanic:</b>			
acid (granites)	1000	78	75
intermediate (diorites)	700	25	30
basic (basalts)	240	10	10
ultrabasic (diabases)	150	0.4	25
<b>Sedimentary:</b>			
limestones	90	27	7
carbonates	—	26	8
sandstones	370	19	10
shales	700	45	45
Phosphogypsum	41	629	18
Coal (Donbass—Kuzbass)	—	18–107	11–74
Coal ash	—	185	85–322
blast-furnace slag	240	70	20
Plaster of natural materials	370	10	6

Measurements made at Zheltye Vody have shown that yet another source of radon in single-story buildings, in addition to those listed above, may be dead waste rocks used for pouring footings.

The danger of that a complex radiation situation may arise in residences of different territories of the USSR means that a comprehensive program should be worked out to study the territory and buildings to assess the danger of the radiation factor for the population. In this connection, the program should be divided into two major components: the first—detection of buildings having an unfavorable situation relative to the radiation factor, and development of steps to reduce its effect on the population; the second—studying the territory of a prospective housing development and working up engineering designs of buildings that preclude the entry of radon and thoron into rooms.

Finding buildings on the territory of the USSR with elevated radiation background presents a certain problem with regard to the number and variability of different factors. In this connection the strategy of the search can be represented as follows:

studying building material quarries and evaluating unconventional materials for their correspondence to NRB-76/87 requirements;

in a case where NRB-76/87 standards are found to be exceeded with respect to natural radionuclides, buildings made from these materials must be examined;

looking for towns and cities located in regions with elevated exhalation of radon from the soil surface. Exhalation may arise at sites of:

shallow occurrence of ore bodies of radioactive deposits and cracked country rock;

development of secondary redispositions of salt dispersion halos of parent elements (especially radium) formed in zones of oxidation of deposits under the action of hypergenic processes both in loose deposits and in bedrock;

shallow occurrence of deposits of nonferrous or ferrous metals, and also phosphate ores that genetically contain considerable amounts of thorium-232 and uranium-238 that are associated with them;

surface outcroppings or shallow occurrence (5-10 m) of acid crystalline rocks, clay shales and their weathering crusts;

ancient geological fractures, cracks and their intersections with formation of zones of fractionation of rocks;

shallow occurrence of aquifers of radon-radium water and zones where they are discharged;

former stockpiles of wastes of mining and industrial enterprises (ash dumps, tailings ponds, gangue spoils, and so on).

Taking as a basis the standards worked out by the ICRP and recommended for use in our nation by the USSR Ministry of Public Health, when the equivalent equilibrium exchange activity of radon exceeds  $200 \text{ Bq m}^{-3}$  in buildings, cosmetic repair must be done that includes the following measures:

removing wooden floors and insulating the subfloor space with reliable synthetic materials;

installing (where necessary) a continuous blower to ventilate the subfloor space;

painting walls with emulsion and oil-base paints, or papering with polymer wall covering (polyamide, polyvinyl chloride, polyethylene);

insulating wooden floors (filling cracks) and cementing linoleum.

These steps should be carried out differentially, depending on the source of radon and its concentration in the air of buildings. In the case of minor and irregular excess of radon and thoron concentrations above standards in rooms, the ventilation process should be intensified, e.g. by installing window fans. For example, intensive ventilation of a room

with volume of  $50 \text{ m}^3$  for  $\frac{1}{2}$  hour reduces the radon-222 concentration by a factor of 2.2–3.5.

In construction development of territories in regions with elevated exhalation of radon from the surface of the ground the following steps should be taken at construction sites:

a gamma survey of the territory in a  $5 \times 5 \text{ m}$  grid (to prevent construction of housing in areas where the exposure dose rate of gamma radiation exceeds  $60 \mu\text{r}/\text{hr}$ );

analysis and zoning of the territory of new construction for exhalation of radon;

laying special foundations of buildings developed with consideration of information obtained in the analysis.

The flux density of radon-222 from the surface of the ground is not constant. It depends not only on the underlying rocks, but also on daily and seasonal changes of meteorological parameters of the atmosphere. The average values of exhalation of radon-222 for some soils of the USSR are summarized in Table 2.

TABLE 2

Radon exhalation from the surface of the ground [5]

Region	Type of soil or rock	Value of exhalation of region, $\text{mBq m}^{-2} \text{s}^{-1}$
Moscow	Podzol	3.8–6.8
Kirov	"	15
Chelyabinsk	Rock	11
Soviet Middle Asia	"	19
Southwest Kazakhstan	Desert	5.0
Dnepropetrovsk	Black earth	9
Zaporozhye	" "	5.0–8.5
Azov Sea Littoral	Sand	1.0
Kirovogradskaya Oblast	Waste rock	34–39
Kirovograd	Loam	10
Zheltyye Vody, Dnepropetrovskaya Oblast	Black earth	13

When considerable radon anomalies are found, a detailed emission radon survey of this terrain should be done to ascertain the nature of the anomaly, and then attack the issue of the feasibility of a housing development on this territory.

When radon exhalation exceeds  $80 \text{ mBq m}^{-2} \text{s}^{-1}$ , the territory is unsuitable for development by conventional buildings. This area can be used for a city recreational park, etc.

In the case where circumstances arise that necessitate housing construction on a territory with high radon exhalation, depending on magnitude, special housing design must be developed. These must account for the following:

special measures of gas insulation must be used in preparing the footings;

the ground story of a multistory building should be used for shops, cafes, restaurants and other general-purpose enterprises with active ventilation;

preparation of the floor of the ground story must include the installation of a gas insulation shield, e.g. of polymer materials;

bringing out all sewage lines into separate ventilated channels, and gas-tight sealing of points of entry of pipes into inhabited rooms;

ventilation of basement rooms by installing separate ducts, blowers, and so on.

These measures are relatively inexpensive, but at the same time are effective.

Thus, problems of locating defective buildings, studying territories for future construction development, and inspecting building materials from the standpoint of radiation safety are urgent issues that must be addressed without delay. Expenditures on cleaning up ill considered measures may be considerably greater, and in some cases with respect to the population may be irretrievable.

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## Compaction of Tailing Deposits in Land Reclamation by Using Energy of Explosion

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UDC 622.882

[Text] The problem of stockpiling enrichment wastes is intimately tied up with ecologically unfavorable conditions of environmental impact. These include the raising of dust of dry shores of tailing ponds, contamination of aquifers, and radon emission in stockpiling of uranium production enrichment wastes. Therefore, problems of finding and developing technological methods of stockpiling wastes, ensuring maximum utilization of the capacity of tailing ponds, and also reclamation of lands that enable makeup of land resources, improve sanitation and health conditions in industrial mining regions.

Existing technology for storing enrichment tailings allows accommodation of material with a density of 1250–1350 kg/m<sup>3</sup>. About 70% of stockpiled wastes are particles of dust fraction that are typified by higher general porosity in dumping (placement), and a three-dimensional network of large cavities that is developed in explicit form. Consequently, the need arises for carrying out steps for additional compacting of wastes (tailings). One of the most promising, least labor intensive, fastest and least expensive methods of compaction in present-day technology of stockpiling tailings is the method of utilizing the energy of explosion.

This paper outlines the results of experimental research on using the energy of explosion to compact wastes of wet concentration at the tailing pond of the mining and metallurgical plant of Eastern Mining and Enrichment Combine. The experiments were done to study the feasibility of explosive compacting of enrichment tailings when they are comparatively thin. In destroying structural bonds of the massif in a certain region around the charge, the energy of the explosion leads to thixotropic fluidization of water-

saturated deposits, resulting in sedimentation of particles and denser repacking. When particles are segregated through a layer of enrichment tailings in the process of consolidation, it should be expected that clay and colloidal particles will be concentrated in the upper layers of deposits, and as the tailings dry out, they will form a dense compacted crust with much lower capacity to raise dust.

In Soviet practice of substantiating and developing technological approaches to the use of explosions for compacting deposits of enrichment tailings, only trial experiments have been done on KMA hydraulic spoils and tailing ponds of Soviet Middle Asia. Positive results of these experiments indicate a good outlook for this direction.

To solve the formulated task, a plan of blasting operations was drawn up with participation of specialists of the department of applied geomechanics of the USSR Academy of Sciences. Based on this plan, two technological approaches to working deposits were selected:

by exploding subsurface charges;

by exploding horizontal elongated charges placed on the bottom of trenches dug in the surface of deposits.

Assuming thickness of deposits  $H = 5$  m, the depth of placement of an individual charge in a hole for compacting the massif by the first approach, according to [1], was

$$h = h_c 1.5 = 3.3, \quad (1)$$

where  $h_c$  is the depth of compaction, m. The mass of the contained charge was  $m = 2.04$  kg.

To place stick charges of explosive 60 mm in diameter at a depth of 3.3 m, a D-10M portable hole digger was used with 75 mm auger. The sticks were bound with two strings of detonating cord and lowered to the required depth. The holes were stemmed with the material taken out when digging. The ends of the detonating cords emerging from the mouths of the holes were connected to lines passing along each row of holes. The latter were connected to a main line through a KZDSh [not further identified] with an increase in steps from II to V (delay interval 20 ms) successively for each row. To find the optimum values of parameters of blasting operations with allowance for specific conditions, several versions of charge placement were used. The distance between charges was determined from the formula

$$L = k \sqrt[3]{Q}, \quad (2)$$

where  $k = 3$  is a coefficient for fine-grained sands with degree of density  $I_d = 0.3-0.4$ ;  $Q$  is the mass of the contained charge, kg.

Formula (2) was used for calculating three sections with different spacing between charges. On the first section, the distance between charges was  $L = 7.6$  m, on the second,  $L = 9.5$  m, and on the third,  $L = 11.0$  m.

The distance between the boundaries of experimental sections was selected in such a way as to exclude the influence of blasting operations on adjacent experimental sections. When working deposits of tailings by explosive horizontal elongated charges placed on the bottom of trenches dug on the surface of the deposits, the mass of the charge was selected with allowance for depth of compaction of the massif  $H = 5$  m and the middle zone effect. In this context, the mass of the charge was

$$Q = \left( \frac{H}{k_g} \right)^3 \frac{1}{W} \approx 0.5 - 0.6, \quad (3)$$

Where  $H = 5$  m is the depth of compaction;  $W$  is the depth of placement of the longitudinal charge (0.4–0.5 m);  $k_g$  is an experimental coefficient that accounts for the strength properties of the ground.

The distance between charges was taken on the basis of the condition that a plane front is set up on the boundary of the zone of residual strains. This distance is 4 m.

To place the horizontal charges, four trenches were dug to a depth of 0.5 m with 4 m between axes. The charge was formed from commercial No 6 ZhV ammonite cartridges 32 mm in diameter massing 0.2 kg placed on the bottom of the trench. After placing two strings of detonating cord along the charge, the trenches were filled with the previously removed dirt and tamped by layers. With allowance for ensuring seismic safety of the dikes enclosing the tailing pond, the mass of the simultaneously detonated explosive did not exceed 20 kg. On each experimental section, blasting operations were preceded by setting observation stations in the form of fiducial marks, and a geodetic survey was made of the surface of the sections to be worked.

After completing blasting operations by the first approach, the surface had settled around each blast hole to a radius of 4–5 m. Immediately after blasting, intensive formation of gryphons was observed around the mouths of the holes, and washout of immobilized water to the surface with fine fractions of sediments. Development of gryphons was observed during the first days after explosive working, and then the washout of pulp from the mouths of the holes stopped.

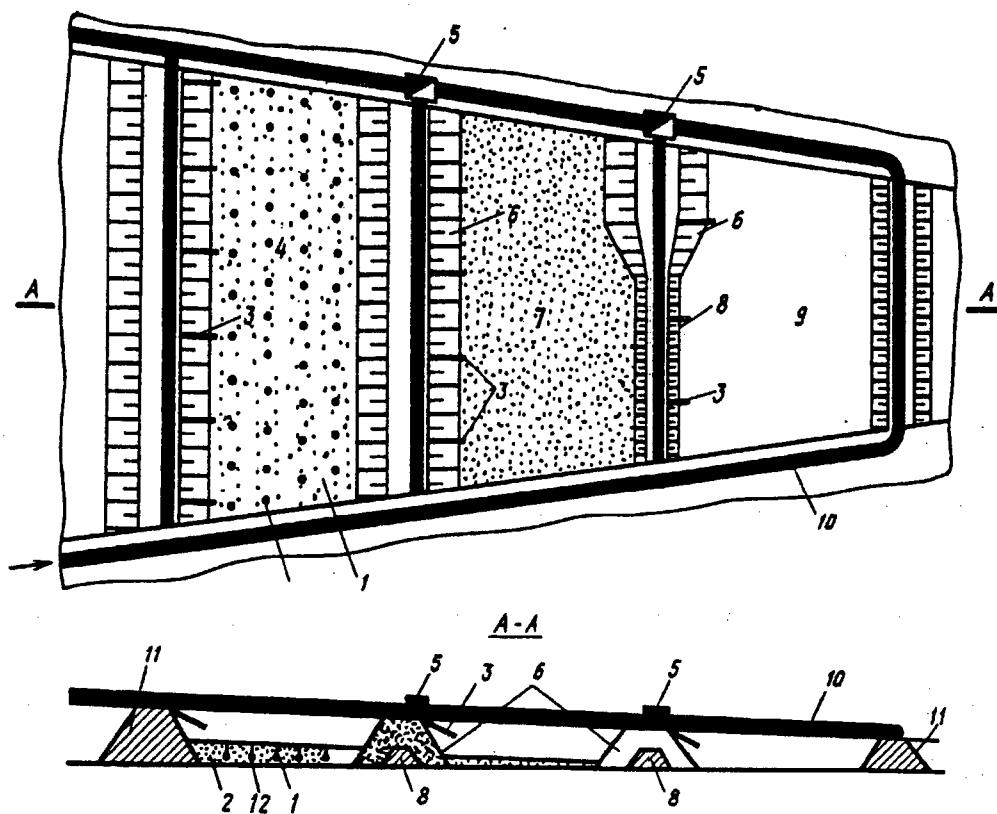
Visual assessment and measurements revealed concentric settling cracks surrounding the holes in the surface layers. The width of opening of these cracks in the zones closest to the holes is 1.5–2 cm with gradual reduction of the opening to 2–3 mm with increasing advancement into the peripheral zones. Spacing between the cracks is constant at 0.8–1.0 m. Maximum distance of settling cracks from the outside rows of holes was 8 m (for mass of unit charges in a row of 2.25 kg) and 10–11 m (for charge mass of 3 kg).

Analysis of the results of an experimental survey done after 15 days showed that the average depth of settling at the mouths of the holes reaches 0.5 m, and in the peripheral sections is 1.5–2 times less. No appreciable difference was observed in the dimensions of settled areas of the surface under charges with different masses (2.25–3.00 kg). Thus, the increase in useful volume with respect to the volume of the section of the massif worked by the blast was ~5%.

On the section with horizontal placement of explosive charges in trenches 0.5 m deep, no settling of the surface of the tailing pond was observed.

Analysis of the results of experimental studies leads us to the following conclusions.

When explosive energy was used to compact tailing deposits, the useful volume of the tailing pond was increased as a result of an increase in the density of the skeleton of the deposits from 1350 to 1450 kg/m<sup>3</sup> and reduction of dust-raising of the tailings. However, the increased density of the skeleton did not lead to the anticipated results with regard to radon emanations, since after blasting, geysering had resulted in surfacing of a considerable volume of silt fraction of the tailings enriched with radium-226, leading to elevation of the exposure dose rate on the surface of the section to 50–80 µR/hr, and hence to increased radon emanations.



Technology of selective stockpiling of tailings with compaction of the silt fraction by explosive energy

In the opinion of the authors, a greater effect with respect to compacting of tailing pond spoils can be achieved by selective stockpiling of the sand and silt fractions of tailings with compaction of the latter by explosive energy (see the figure). For this purpose, loam is first used to make two main fill dikes 11, the territory between them is partitioned into modules 4, 7, 9 by building pilot fill dikes 8 from gangue. The tailing pond is filled through dredge piping 10 and cyclone separators 5, where the tailings are divided into sand and silt fractions. The silt fraction is dumped through discharge pipes 3 alternately into modules 4, 7, 9, and the sand fraction is washed onto pilot dikes 8, forming sand dikes 6.

As soon as the thickness of the deposits of silt fraction 1 on module 4 reaches 5–6 m, dumping of tailings on this module stops, and switches to module 7. After holding, a checkered grid of holes 2 3 m deep is made in module 4. After drilling has been completed, the holes are charged with stick explosive No 6 ZhV ammonite) 12. The simultaneous amount of detonated explosive is determined depending on the seismic stability of the dikes. After blasting, the module is held until the rated compaction is attained, after which the discharge of silt fraction is renewed. Similar operations are done on modules 7 and 9. Filling and holding of all modules is followed by reclamation.

The first results of the experiment have shown that when a tailing pond with area of 300 ha and thickness of tailing deposits of 10 m is worked by explosives, approximately another 1.5 million metric tons of tailings can be placed, which gives an economic effect to the enterprise that considerably covers expenditures on blasting operations.

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## Geotechnologist Mining Engineer

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[Article by D. P. Lobanov, doctor of technical sciences, Moscow Institute for Geological Exploration imeni Sergo Ordzhonikidze]

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[Text] In the ancient and honorable trade of the mining engineer, the fleeting time, complication of the conditions of formation of the mineral and raw material complex of the national economy, and increasingly stringent economic and ecological constraints on the use of mineral wealth are stimulating the search for fundamentally new approaches, principles and technologies in the extraction of mineral raw material.

GORNYY ZHURNAL has acquainted readers with one of the possible fundamentally new directions of the revolution in science and engineering in mining sectors of industry: geotechnology.\* As of now, a definition of geotechnology has been formed as the science that studies the conditions, means and methods of working solid minerals by converting them in situ at the deposit to a mobile state with subsequent extraction of the productive fluid to the surface.

The technical level and scales of development of geotechnology depend on many factors, the most important of which is the availability of trained geotechnologist engineers.

On the basis of specialized area 09.02 ("Underground Working of Mineral Deposits"), the training of geotechnologist mining engineers for specialization 09.02.03 ("Working Deposits by Geotechnological Methods") is being done in the Department of Geotechnology of Ores of Rare and Radioactive Metals (Moscow Institute for Geological

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\*V. Zh. Arens, "Status and Problems of Geotechnology," GORNYY ZHURNAL, No 12, 1987, pp 32-35.

Exploration imeni Sergo Ordzhonikidze), where considerable scientific and procedural experience has been accumulated in training of specialists in this pioneering field.

The classification characteristic of the geotechnologist mining engineer completely accounts for the current concept of a radical transition to intensive development of the mineral raw material complex of the nation with curtailment of working of new mineral deposits, dramatic reduction of losses on all process stages (searching, exploration, development, enrichment, processing), a radical change in the ecological and economic substantiation of engineering approaches, and considerable improvement of working conditions based on practical introduction of methods of geotechnology and geobio-technology.

*Occupation of geotechnologist mining engineer.* The specialist is trained for production-technological, organizational-management, planning-design and scientific research activity in the area of no-waste, resource-saving, ecologically clean technologies for extracting solid minerals by physicochemical and bacterial methods based on converting them in situ at the deposit into a new phase state (solution, liquid mixture, gas) that is convenient for continuous transport and processing.

The geotechnologist mining engineer works at mining enterprises, geotechnological complexes, on experimental industrial sections, in design and planning organizations and scientific institutions in positions of shift chief, head of a section or experimental industrial proving ground, science aide of a geotechnological expedition or laboratory. Such an engineer may be of use in the exploratory and operational small enterprises and joint ventures now being formed.

A high level of professional training is based on fundamental, general engineering, and mining geological cycles of disciplines, research training, and practical instruction. Development of broad erudition and general high culture, in-depth understanding of transformations in all spheres of the life of the nation, and a consciousness of the necessity of a personal contribution to scientific-technical progress of the mineral raw material complex of the national economy are organically integrated into the entire system of training of the specialist. An inseparable part of the individual plan of instruction is development of the future engineer's aspiration and ability to continually enlarge his professional knowledge, expand his outlook, master the art of supervising a work team, and develop economical methods of management.

*The geotechnologist mining engineer knows:*

the basics of socioeconomic and fundamental sciences in the volume necessary for understanding and taking part in carrying out measures of scientific-technical progress in the mineral raw material complex of the nation, the laws of development of hardware components;

general engineering disciplines, including: mining engineering graphics, physics of rocks, electrodynamics, thermodynamics and hydrodynamics, the basics of electrical engineering and electronics, applied mechanics;

geological, hydrogeological, geophysical and geochemical principles of the formation, spatial location, prediction and classification of industrial types of deposits of ferrous, rare, radioactive and noble metals and diamonds, and also nonmetallic minerals, the particulars of composition of ores of these deposits, modern methods of comprehensive investigation, exploration and prospecting, the ecological logging of a deposit;

mine-engineering and economic-ecological principles of opening, preparing, mining operations, mechanization and automation, organization and management of production in underground, open-pit and combined methods of extracting ores of nonferrous, rare, radioactive and noble metals, and also diamonds, including mine surveying, mine aerology and enrichment of solid minerals;

the principles of underground physical processes, methods and means of controlling mine pressure, monitoring the state of rock, physical methods of destroying rocks, engineering and technology of blasting operations;

geotechnological methods of extracting raw material, mining-geological, hydrogeochemical and ecological-socioeconomic conditions of applying them, specifics of engineering processes of extraction, mechanization and automation of production;

special geotechnological disciplines that reveal the resource-saving features of a method, theoretical principles of physical, chemical, physicochemical and geobiological processes and the patterns of their behavior in the ore bed or extracted ore, methods of controlling the kinetics of the process and treatment of the products of geotechnology;

systems and geotechnological complexes in underground dissolution, smelting, gasification, leaching, hydrotechnology, using natural geothermal resources, underground mineralization of water, and also in working technogenic deposits; determination of the annual productivity of the geotechnological enterprise, the order of introduction of sections and modules into service, economic substantiation of selected technological approaches;

basics of remote control of continuous physical, chemical, physicochemical and biological processes in situ at the location of the underground mineral deposit and on the surface of geotechnological complexes;

basics of technology of heap leaching of metal from lean and extra-balance ores, and its use when planning the working of deposits by conventional methods and shaft systems of underground leaching;

basics of ecology of technogenic landscapes and geotechnological production, methods of studying an ecological situation, information processing; principles and methods of restoring ecosystems, basics of legislation on mineral resources and environmental protection;

sanitary rules of planning, setting up, operating and dismantling geotechnological underground leaching enterprises, and also their specifics during the post-operational period.

*The geotechnologist mining engineer knows how to:*

forecast the outlook for deposits that have been explored and are being developed with regard to the possibility of working (further development) by geotechnological methods or in combination with conventional methods;

evaluate the feasibility of working technogenic deposits by methods of geotechnology or in combination with conventional methods;

set up, carry out and analyze the results of laboratory, field and experimental industrial geotechnological studies for different types of deposits and corresponding methods of development;

use hydrogeological, radiometric, x-ray spectral and other methods of analyzing and monitoring products and processes of geotechnology, as well as modeling the hydrodynamic stage of underground leaching on analog and digital computers;

design geotechnological systems, sections and modules with allowance for current trends, and Soviet and foreign engineering advances, draw up requests for proposals on reconstruction of an existing enterprise for additional development by geotechnological methods;

organize effective and safe extraction and processing of products of geotechnology, study and monitor physicochemical processes in a mineral massif, plan and carry out real-time regulation of a continuous technological process;

control the state of a rock mass, making the necessary predictions and carrying out steps to prevent dynamic phenomena on geotechnological complexes;

develop procedures for geotechnological processes, carry out engineering calculations of structural parameters of mining systems, compare technical-economic requirements on designing new systems and create new instruments, mechanisms and machines for extracting and processing products of geotechnology;

develop and operate geotechnological wells, means of destroying and loosening (fractionating) rocks, transporting and raising products of geotechnology, and processing them;

determine and carry out steps in accordance with sanitary rules for a geotechnological enterprise on exploration, planning, construction, operation and dismantling, as well as on the post-operational period with consideration of physical geographic and socioeconomic conditions of the region of the deposit and the particulars of the enterprise itself;

use effective methods of retrieving and utilizing scientific and engineering information, methods of working with modern computer equipment, using CADS;

independently make sound engineering decisions, and carry out real-time operations on supervising the final work, advancing his own skill and that of his subordinates, promote the development of the innovation and invention movement in a collective based on methods of morphological and functional-cost analysis and synthesis in engineering;

use methods of finding fundamentally new technological approaches using a data bank on effects (physical, chemical, biological) or a knowledge bank, and also expert or logistic systems.

From this brief qualifications description of the geotechnologist mining engineer, we can conclude that training of a specialist in the new profile is based on the methodology of engineering creativity focused not only on developing equipment and technology on an up-to-date level, but also upgrading it. The demand for such mining specialists will grow together with an understanding of the necessity for a strategic solution of problems of rational management of natural resources, conservation, improvement and protection of the environment.

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